YEARBOOK

CENTRAL RESEARCH INSTITUTE for PHYSICS

OF THE HUNGARIAN ACADEMY OF SCIENCES

1989-91

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MTA • KÖZPONTI FIZIKAI KUTATÓ INTÉZET

CENTRAL RESEARCH INSTITUTE FOR PHYSICS
HUNGARIAN ACADEMY OF SCIENCES

BUDAPEST

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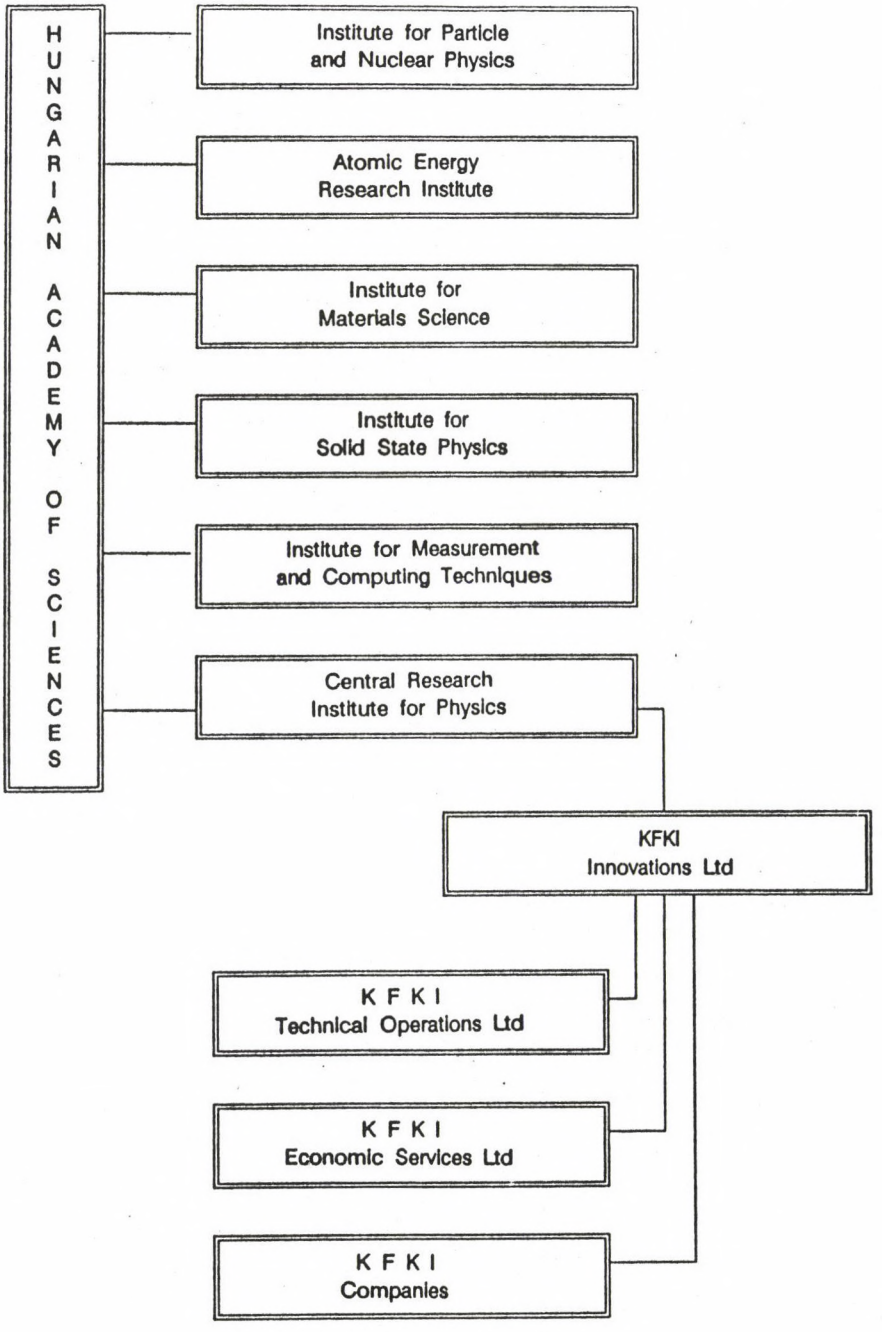
Preface

The Central Research Institute for Physics of the Hungarian Academy of Sciences (generally known by the Hungarian abbreviation KFKI) went through an important change of structure in the recent past. As a result of the reorganization accomplished after two-year preparation the following institutions became legally independent:

KFKI Research Institute for Materials Science
KFKI Atomic Energy Research Institute
KFKI Research Institute for Measurement and Computing Techniques
KFKI Research Institute for Particle and Nuclear Physics
KFKI Research Institute for Solid State Physics
KFKI Innovations Ltd

The new system of relationship is shown on the next page. The total number of staff of the KFKI was 2000 in January 1990. After the reorganization altogether 1000 persons remained at the research institutes, among those about 60 at the MTA KFKI. From the other 1000 persons about 600 are working in the staff of the KFKI Innovations Ltd. The staff-numbers of the institutions are given in the following table:

KFKI Research Institutes	
Research Institute for Materials Science	*136*
Atomic Energy Research Institute	*268*
Research Institute for Measurement and Computing Techniques	*122*
Research Institute for Particle and Nuclear Physics	*259*
Research Institute for Solid State Physics	*160*
MTA Central Research Institute for Physics	
Management	*18*
Library	*15*
Computer Network	*27*
KFKI Innovations Ltd	
Technical Operations Ltd	*150*
Economic Services Ltd	*20*
Companies	*430*


HUNGARIAN ACADEMY OF SCIENCES
Institute for Particle and Nuclear Physics
Atomic Energy Research Institute
Institute for Materials Science
Institute for Solid State Physics
Institute for Measurement and Computing Techniques
Central Research Institute for Physics
KFKI Innovations Ltd
K F K I Technical Operations Ltd
K F K I Economic Services Ltd
K F K I Companies

MTA KFKI
MTA Central Research Institute for Physics

The basic activity:

Legal successor of the former MTA KFKI.
Owner of the KFKI Innovations Ltd.
Running the Library.
Running the Center of Computer Network.
Gestor of the Budapest Research Center of Materials Science.
Coordinator among the KFKI Research Institutes and Universities.

KFKI ATKI
KFKI Research Institute for Materials Science

Research:

non-equilibrium systems (systems produced by ion implantation, laser irradiation and rapid solidification, etc.);
study of epitaxial and disordered thin films surface studies (scanning tunnel microscopy);
formation and interaction of lattice defects;
study of atomic environments;
"nanotechnology" (production of low-dimensional structures);
production of sensors;
magnetic and ferroelectric phenomena;
modelling of processes in crystal physics;
analytical work for environmental protection;
bioelectronics;
materials transport by diffusion.
Development:
integrated circuit technology, crystal growth, computer control, ellipsometry, ion sources.

KFKI AEKI
KFKI Atomic Energy Research Institute

Research and development:

reactor physics, reactor diagnostics, health physics, real-time information and consulting systems, reactor-simulation, deterministic and probabilistic analysis of the safety of nuclear power plants, analysis of severe nuclear accidents, radiation-damage, fracture-mechnics, detection of leakage, deterministic and probabilistic analysis of the safety of dangerous industrial

facilities, environmental protection, control systems for the environment, risk analysis, analytical chemistry, physical chemistry, acoustical emission, reactor electronics, space electronics, aviation diagnostics.

Operation:
research and zero-reactors.

KFKI MSzKI
KFKI Research Institute for Measurement and Computing Techniques

Research:
parallel computer architectures; software for computers with parallel architecture;
image recognition and processing; algorithm-oriented architectures; data-transmission methods;
object-oriented simulation methods;
planning and description of information systems; artivicial intelligence.
Development:
laboratory measuring techniques and instrumentation;
software technology; modelling of industrial and electrical energy systems.

KFKI RMKI
KFKI Research Institute for Particle and Nuclear Physics

Research:
particle physics (hadron-hadron, lepton-hadron, and lepton-lepton reactions);
nuclear physics (nucleus-nucleus, hadron-nucleus reactions);
plasma physics (thermonuclear plasma physics, laser physics,
physics of the atomic shell and modecules);
space physics (solar wind, planets, cosmic radiation);
theoretical physics (nuclear physics, particle physics, theory of relativity);
materials science (disordered structures, ion implantation, surface leyers);
biophysics (environmental research, analysis of proteins and biological samples, neural networks).

Development:
laser techniques, nuclear analytics, space technology, fast data-processing, optical and X-ray spectroscopy.

Operation: accelerators and fusion facilities.

KFKI SzFKI
KFKI Research Institute for Solid State Physics

Research:

theoretical solid state physics;
the physics of partially ordered condensed matter (low-dimensional systems, superconductors, amorphous semiconductors, liquid crystals);
physics of metals;
laser physics.

Development:

laser techniques, amorphous alloys and metal galsses, material testing instruments, and optical thin film equipment;
NMR measuring techniques, Mössbauer spectroscopy,
neutron spectroscopy, neutron radiography,
techniques of X-ray diffraction and scattering, and techniques of ultrashort light pulses.

In this yearbook the five - already independent - research institutes give account of their most important results reached in the period between January 1989 and December 1991.

Director General

CONTENTS

INSTITUTE FOR MATERIALS SCIENCE

ATOMIC ENERGY RESEARCH INSTITUTE

KFKI RESEARCH INSTITUTE FOR PARTICLE AND NUCLEAR PHYSICS (RMKI)

Space Research and Cosmic Physics

Research activities were concentrated around two major projects: the VEGA cometary encounter mission of 1985-86 to Halley's comet and the 1989-90 PHOBOS mission to Mars. Pictures of the nucleus of Halley's comet have been further analyzed, and implications of plasma, particle and field measurements in cometary and planetary environments have been studied. Acceleration processes have been investigated both from observational and theoretical viewpoints. A simulation study of the behaviour of dust in the Mars environment has been made. Theoretical investigations of the modulation of galactic cosmic rays have been continued.

Image processing of the pictures of Halley's comet taken by the two VEGA spacecrafts has been continued in cooperation with the Astronomical Institute of the Hungarian Academy of Sciences. The VEGA-1 images were out of focus, this error has been corrected using the point-spread function of the optical system. The angular coverage was almost 160 degrees for VEGA-1 and about 70 degrees for VEGA-2. Based on these image sets the three-dimensional shape of the nucleus was reconstructed. The shape of the nucleus was found to be very irregular. The main dimensions are 16 km, 7.2 km and 7.2 km with .5 km uncertainties, the ratios of the principal moments of inertia, supposing homogeneous density, are 1 : 3.3 : 3.4. Some features can be identified on the surface of the nucleus if albedo variations are neglected and brightness variations are assumed to be due to slope variations only.

During all three flyby missions (VEGA-1, -2, and GIOTTO) there were active regions close to the subsolar point. The prominent jet activity always pointed sunward. Ground-based observations have revealed recurring jet patterns.

Hungary is participating in the preparation of an atlas of VEGA images for the archives of the International Halley Watch.

The plasma environment of comet Halley was further investigated on the basis of the comparison of plasma, magnetic field, and plasma wave data measured aboard the VEGA-2 spacecraft. Physical processes were studied in the vicinity of the cometopause which separates the solar wind controlled cometosheath from the inner plasma region dominated by heavy cometary ions. The increase in the level of both lower hybrid and whistler mode plasma oscillations is a consequence of the rapid mass-loading and deceleration of the solar wind by cometary ions.

In order to explain the large-scale increases in the flux of energetic ions, the formation of periodic structures of cometary neutrals was assumed, which, in accordance with our trajectory calculations of neutrals, leads to an expansion speed much larger than expected. Based on the data of the energetic particle instrument aboard VEGA-1, energy spectra of ions in the range of 100 to 800 keV were deduced along the VEGA path. These spectra have been reproduced by a one dimensional time dependent model of velocity and spatial diffusion in the cometary preshock region. The calculations suggest that ions are accelerated by a second order Fermi process up to moderate energies, thus forming a seed population to the more effective diffusive-compressive shock acceleration. A numerical code to describe the dust-gas interaction in the cometary coma has been developed.

Recurrent enhancements of energetic particle fluxes recorded on-board VEGA-1 and -2 during the first half of 1985 formed a long-lasting series of events in the decreasing phase of the 21st solar activity cycle. By combining the data with those of 1 to 2 MeV protons measured on the IMP-7 and -8 spacecraft, a relatively high stability of the phase of maximum was found for a time span as long as 26 solar rotations.

The two PHOBOS spacecraft were launched on July 7 and 12, 1988 respectively. The mission was planned to have three stages:investigations of the sun and interplanetary plasma during the cruise phase to Mars, exploration of Mars and its environment during orbits around the planet, and study of the Martian moon Phobos, including both remote sensing and the soft landing of a module on its surface. Due to the unfortunate loss of radio contact during the first phase, PHOBOS-1 was lost before reaching Mars. PHOBOS-2, however, completed both the first and second stages. On January 29, 1989, it was transferred to an elongated elliptical orbit around Mars with a pericenter of about 860 km. A novel feature of the orbit was that it crossed the bow shock close to the subsolar point, and deeply penetrated the Martian shadow cone, thus providing detailed information about the plasma of the magnetotail. About 2 hours preceding and following pericenter passages, data taking and telemetry worked in the fast mode. After about five elliptic orbits the spacecraft was transferred to an almost circular orbit close to the orbit of the Phobos moon, and stayed there for more than 100 orbits. Before reaching the third stage, the mission ended on March 27 due to the loss of radio contact.

We participated in the work of four of the plasma and field instrument groups. The HARP hyperbolic electrostatic analyzer was manufactured and assembled in Hungary. Thermal and suprathermal electron and ion spectra were measured in the energy range of 0.25 to 850 eV, in 75 logarithmically spaced energy channels and in 8 simultaneously sampled angular sectors pointing away from the sun. The TAUS spectrometer used both electric and magnetic fields for separating three types of ions (protons and alpha particles characteristic of the solar wind, and 'heavy ions' of predominantly Martian origin, characterized by a mass to charge ratio of 3 or more). The energy per charge range was 30 V to 6 kV, subdivided into 32 channels. The SLED twin particle detecting system measured ions and electrons in the range of 30 keV to several MeV in 6 intervals. The LET device measured spectra and elemental compositions of energetic particles, from protons to iron ions, in the energy range of 1 to 75 MeV/nucleon, using a solid state detector telescope mounted on a rotating platform.

Data evaluation and interpretation was concentrated first on the most interesting period of the mission, when PHOBOS-2 approached Mars to about 860 km on the elliptic orbits, and when it crossed the tail on the same orbits. Solar and interplanetary particle research had a high priority for the LET and SLED instruments, and several interesting results have already been published on a series of energetic particle enhancements associated with corotating interaction regions and with large flare particle events.

In the Mars environment, several important new observations were made by the the PHOBOS-2 instrument groups. Upstream of the bow shock, a detailed picture of wave activity and associated electron acceleration and magnetic field perturbations were seen. Ion outflow events were detected both in the upstream region and closer to the planet. A surprisingly large and both spatially and temporarily variable ion outflow activity was seen in the tail region. The interpretation of plasma and field observations of the boundary (or boundaries) named planetopause/magnetopause is still controversial. The SLED instrument detected some intensity enhancements in the range of 30-350 keV at approximately 900 km altitude in three subsequent elliptic orbits, for which no convincing interpretation exists so far. The HARP instrument detected a previously unknown hot electron component in the tail region.

Irregular plasma and magnetic field disturbances were observed aboard the Phobos 2 spacecraft in a few cases when it crossed the Phobos moon's orbit. At the times when the disturbances were detected, the distance between the moon and the spacecraft was several thousand kilometers, about an order of magnitude larger than the characteristic dimension of the disturbances. These observations raised questions about the possible existence of a dust torus around Mars. The origin of dust grains can be attributed to micrometeoroid bombardments on the surface of the Martian satellites. The motion of ejected particles larger than 1 micron is mainly influenced by gravity. On the other hand, the orbital evolution of submicron-sized grains can significantly be influenced by solar radiation and by

Lorentz forces since the particles collect charges in the interplanetary field and in the induced magnetosheath of Mars. We investigate the trajectories and lifetimes of particles in the size interval of 0.05-1 micron which were ejected from Phobos at velocities larger than the escape velocity (4-14 m/s), but much smaller than the orbital speed of the moon. All dust grains are launched to circular orbits corresponding to the Keplerian orbit of the moon. The 24 degree obliquity between the orbital plane of Mars and that of the moon was taken into consideration. The Martian magnetosheath was described by an earlier developed gasdynamic model. The parameters of the interplanetary field were taken either as constant corresponding to the typical values at 1.5 AU or as varying by simulating two high speed streams during one solar cycle.

The size range which is significantly influenced by electromagnetic forces,depends on the interplanetary parameters as well as on the orbital position of Mars at the time of the ejection of the grain. Very small particles are blown away by the solar wind very soon, i.e. they leave the Martian environment a few days after they were ejected. Larger grains of a certain size interval may stay in orbit longer than in the case when Lorentz forces are ignored. The particles which are kept in orbit by the perturbation effect of the Lorentz forces for several weeks or months, are larger when they were ejected at equinox compared to the 'long-living' particles at solstice. Therefore we expect that the number of smaller particles exceeds the number of larger particles after solstice, while larger particles dominate after equinox. Submicron-sized grains form a time-dependent and non-uniform dust halo around Mars. If there is a dust belt along the orbit of Phobos, it must consist of particles much larger than 1 micron.

Acceleration of charged particles by quasi-perpendicular interplanetary shocks has been studied in collaboration with the Imperial College (London, U.K.). Based on ISEE-3 measurements, angular and spectral behaviour of particle populations have been determined through shocks, and compared to the predictions of the so-called gradient drift acceleration model. Time reversed numerical simulation of particle trajectories resulted in a smooth transition of particle flux across the shock implying that, with the assumption of simple planar geometry, particle enhancements close to the shock ('shock spikes') are not readily explainable by the scatter-free acceleration alone.

Research in the field of cosmic ray modulation has been continued in collaboration with the University of Arizona, Tucson, USA. A 3-D time-dependent numerical code has been developed to solve the general transport equation of charged particles in the heliosphere including all major physical processes: diffusion, convection, drift, adiabatic cooling, and acceleration. The present model incorporates a wavy heliospheric current sheet and a solar wind profile with minimum speed at the sheet and increasing wind velocity away from the sheet. The model gives rise to shocks, corotating interaction regions, and merging interaction regions in a natural way, and it successfully predicts several otherwise unexplained features of cosmic ray modulation, such as the change of latitudinal gradient, and

the correlation of the cosmic ray flux with the tilt-angle of the neutral sheet. It has also been pointed out that the classical Parker spiral model of the interplanetary magnetic field has to be revised: at the poles the regular Parker field falls off rapidly and should be dominated by an irregular transverse field component. The supergranular motion of the solar surface was noted as a possible source of the predicted transverse field.

The acceleration and modulation of the anomalous cosmic ray component has also been studied. By calculating the energy spectrum and density of various cosmic ray components, it was concluded that the termination shock of the solar wind might be as far out as 80 a.u., while at larger distances the extrapolated energy density of anomalous cosmic rays reaches that of the solar wind.

A new form of pitch-angle distribution was proposed for galactic cosmic rays in a focusing heliospheric field. In a theoretical work, it has been suggested that the pitch-angle distribution of galactic particles may differ from that of solar cosmic rays, and the difference becomes significant at large values of the scattering mean free path where focusing is strong. The results have important implications on the transport parameters (diffusion coefficient, effective convection) when the irregular component of the heliospheric magnetic field has a dominant helicity.

Experimental Particle Physics

CERN collaborations:

The direct photon studies (NA24 collaboration) has been consluded by publishing the results on direct γ-γ production at 300 GeV/c. The observed γ-γ-signal was in good agreement with QCD predictions. The heavy ion studies at CERN-SPS were continued. The sulphur-beam, provided by the new ion source, bombarded the target with particles of 6.4 TeV total energy (200 GeV/nucleus). The behaviour of hadronic matter at high density and temperature was investigated. Results on strangeness production and pion interference were obtained (NA35 collaboration). In response to the LHC challenge, to solve the data acquisition and processing bottle-neck a massively parallel computing initiative was launched at CERN. In this context work has been started on the Associative String Processor (ASP) architecture. Application areas in high energy physics were identified and algorithms were developed. (MPPC collaboration)

Using the European Hybrid Spectrometer (EHS), "high mass" diffractive dissociation has been investigated for $pp \rightarrow pp + \pi + m\pi^0$ ($m = 0,1,2$) final states. The decay of the diffractive system is seen to be very anisotropic and large p_T is suppressed. Analysing the events in Gottfried Jackson frame of the excited system, it is found that, besides the "pomeron"-single quark coupling, diquark-"pomeron" coupling also exists. In this case, as the charge ratio ($uu/ud = 0.17 \pm 0.10$) suggests, the diquark tends to be "ud". Bose-Einstein correlations of pions, investigated at the same energy, give an effective radius $r = 1.02 \pm 0.20$ fermi with a chaoticity factor $\lambda = 0.32 + 0.08$ and there is no multiplicity dependence.

The revival of interest on light meson spectroscopy in recent years is mainly linked with the possibility of proving the nonabelian nature of QCD, which gives origin to direct coupling between gluons. The existence of glue balls and hybrids would be proof of this. The aim of the Crystal Barrel Spectrometer experiment at the Low Energy Antiproton Ring is to investigate the $\bar{p}$ p (n)- annihilations at rest and in flight up to 2 GeV/c. A small group of us joined this experiment in November 1989.

The L3 Collaboration at the LEP collider in CERN finished the construction of the L3 detector and the research programme started in 1989. We measured the neutral current coupling constants to leptons, as well as the vector and axial vector coupling constants. Mass limits have been determined for scalar muons, scalar electrons and winos near $s = 91$ GeV. We have made a precise measurement of the cross section for $e + e^- \rightarrow ZO \rightarrow$ hadrons and determined the mass and width of the ZO boson. Mass limits have been given for excited electrons and muons from ZO decay. We have studied the $ZO \rightarrow$ b anti-b decay properties. From our measurement of the partial width and the mass of the ZO boson we determined the effective electroweak mixing angle and the neutral current coupling strength parameter. Searching for the neutral Higgs boson in ZO decays, whose existence is predicted by the Standard Model, lower limits have been given for the mass of the HO. A minimal Standard Model Higgs boson in the mass range $2 < m_{HO} < 32$ GeV is excluded by our analysis. We performed a test of QCD based on 4-jet events from ZO decays and, from the study of jet multiplicities, we measured the strong coupling constant a_s. Finally, one of our basic results concerns the number of families of quarks and leptons. We precisely determined the number of neutrino species and the possibility of four or more neutrino flavours is ruled out. Furthermore, our analysis excluded the existence of a supersymmetric scalar neutrino having mass less than 31.4 GeV.

Collaboration with JINR (Dubna)

RISK experiment

The experimental data were obtained using the RISK streamer chamber magnetic spectrometer. The chamber was triggered by outer detectors when the charged secondary with transverse momentum above 1 GeV/c ("trigger particle")

was produced. We observed a noticeable increase with target mass number A for the mean square of the projection of associated particle transverse momenta onto the normal to the trigger particle production plane. The results are explained as a manifestation of the high p particle production via the nuclear rescattering of the primary particle or its constituents.

Baikal experiment

We are taking part in the construction of the first large deep underwater detector in Lake Baikal in order to study neutrino physics, cosmic ray physics and particle physics.

Neutrino calorimeter

The proton beam dump experiment at 70 GeV using the IHEP-JINR neutrino detector was designed to investigate prompt neutrinos from charm production and exotic particles. A search has been performed for weakly interacting neutral light scalar and pseudoscalar particles. No positive signal has been observed within the frame of the Standard Model and its minimal supersymmetric extension. The Higgs particles of the SU x U Standard Model are excluded for masses in the range 1.1 MeV $< m_H <$ 102 MeV at 95% CL. Limits on the Peccei-Quinn like axions are also derived. In this collaboration we participated in the work of the Fourier microscope group. This is a new device for high energy physics, designed for observing straight line particle tracks in nuclear emulsion. The Messo-optical Fourier Transform Microscope works without any mechanical or electronical depth scanning and can be considered as a selectivity viewing "eye".

A computer program has been developed in our department for the simulation and graphical interpretation of some special processes of nature. Applications of this program in various areas of physics and biology are in progress.

We have continued our phenomenological study of multiplicity distributions obtained by means of a generalized geometrical model in the impact parameter representation. Good agreement has been found between the model and the experimental results in respect of the higher scaled moments in hadron-hadron interactions at s = 10-900 GeV. On the basis of a new empirical regularity we have predicted the multiplicity distributions for Tevatron, LHC, SSC and, in e + e- annihilations, for SLC and LEP energies. Our prediction proved to be in excellent agreement with the recent measurement of the DELPHI Collaboration at LEP-1 energies. We have also investigated the Feynman fluid analogy in e + e- annihilations and determined the pressure-fugacity function in the thermodynamic limit. No indication of a phase transition point was found. Introducing the concept of statistical distance we predicted a remarkably simple relationship between multiplicity distributions and Poisson distributions beyond Tevatron energies: We expect that the ratio of the maximum available rapidity and the logarithm of the two- and three-particle correlation parameters becomes energy independent up to SSC energies. Another application of statistical distance has been proposed to characterize the approach to KNO scaling in place of the usual KNO plot analysis.

Investigations on relativistic invariant quantum measurement theory have been initiated, using field theoretical techniques.

High Energy Nuclear Physics

The scientific programme related to the study of particle production by 300-550 MeV neutrons, performed at SIN (now PSI) in cooperation with the team from Freiburg University, has now been completed. The energy spectra of protons, deuterons and tritons as well as those of charged pions were measured in the angular range from 54° to 164° using C, Cu and Bi nuclei as targets. In accordance with the preliminary results, scaling behaviour of the inclusive cross sections was found for heavy reaction products in all cases, being most prominent in the case of carbon. A rather simple empirical formula was found to describe the energy and angular dependence of the cross section and it was analysed in terms of quasi two body scaling as well as in terms of the moving source model. The energy spectra of charged pions were fairly well understood in terms of the cascade model.

The structure of the deuteron wave function at large internal momenta was investigated by means of exclusive dp → ppn break-up reactions using 2 GeV vector- and tensor-polarized deuterons. The coincidence experiment was performed at the Laboratoire National Saturne (Saclay) in a Leningrad-Saclay-Budapest collaboration. The reaction cross section as well as the vector and tensor analysing powers have been determined up to internal momenta 0.4 GeV/c. Preliminary results show that, in contrast to measurements investigating lower internal momentum regions, rather large deviations from the impulse approximation were observed above 0.2 GeV/c. This can partly be understood by including double-scattering terms in the matrix element of the interaction.

A new experimental programme was started to investigate heavy-ion collisions near 1 GeV/nucleon energies at the heavy-ion synchrotron (SIS) at GSI, Darmstadt. In the framework of the 4π-detector collaboration, construction problems related to the HELITRON radial drift chamber were investigated and model measurements performed.

With the support of the Hungarian Academy of Sciences and the National Science Foundation of the USA an experiment was carried out in a collaboration of the Loránd Eötvös University, Budapest, the Central Research Institute for Physics, Budapest, and Michigan State University, USA. The reaction mechanism of intermediate energy heavy-ion collisions was studied using the K500 superconducting isochronous cyclotron of the MSU. Fragmentation and the fragment sequential neutron decay were investigated with 35 and 50 MeV/nucleon energy $^{14}N^{5+}$ and 35 MeV/nucleon $^{36}Ar^{11+}$ beams.

Together with the University of British Columbia we have studied the reaction $p\,p \rightarrow p\,p\pi^{o}$ near the energy threshold, at five energies between 320 and 500 MeV.

The work was performed on the polarised proton beam of TRIUMF. The decay photons from the π^0 mesons were detected in coincidence by two large NaI(Tl) crystals, TINA and MINA, as a function of the incident proton energy and the angles of photon emission. Our result agrees with the previous measurements but is of a much higher precision. The theoretical predictions, obtained by the soft pion method of Efrosinin et al. and by the non-relativistic calculations of Koltun and Reitan, are close to our measured values.

An experiment was performed at Brookhaven to measure the branching ratios of radiative hyperon processes following the strong capture of K- mesons in the K^-p and K^-d atoms. Our goal was to obtain information on the quark structure of the hyperons. In the first stage of the experiment we have simultaneously measured the branching ratios of the radiative kaon capture reactions producing Lambda and Sigma-0 hyperons together with photons and that of the weak radiative decay (WRD) Sigma$^+$ → p + gamma. Negative kaons of 650 MeV/c momentum were stopped in liquid hydrogen and deuterium, the incident kaons were identified using time-of-flight, lucite Cerenkov counters and plastic dE/dx scintillators. The radiative capture measurements were made possible by a new, segmented, previously unattainable resolution (1.3% FWHM for 129.5 MeV photons) NaI detector. The measured values for the branching ratios show that none of the available theoretical calculations can predict correct branching ratios for the radiative capture. For studying the Sigma$^+$ WRD two range telescopes and the Stanford NaI array of 7*7 segments were used, simultaneously with the kaon radiative capture studies. About 400 Sigma$^+$ WRD events were collected which doubles the world total of the six previous experiments and the result is consistent with the previous measurements.

Low Energy Nuclear Physics

Identification of the 1g9/2 states in the f-p shell nuclei is possible even when the analog states are fragmented, because of their relative isolation. The most important source of information on the fregmentation of the IAS is the R-matrix analysis of the differential cross sections of (p,p_0) and (p,p_1) reactions. For higher-spin resonances ($J > 7/2$) proton capture seems to provide important details, where the principal gamma decays proceed to the antianalog states (A-AA), and other higher-spin states are populated.

Hindrance of the M1 A-AA transition was found and different assumptions were introduced to interpret it. Considering the fragmentation of the single-particle and analog states, we think that this may have an effect on the strengths of the A-AA transitions.

The fragmentation of the $1g^{9/2}$ IAS of the $^{60}Ni + p$ was investigated where in the ^{61}Cu daughter nucleus there are at least two 9/2 + states at low energies, thus

showing the fragmentation of the AA state. To locate these eleven fragments ^{60}Ni(p,p1,gamma) and ^{60}Ni(p,gamma) ^{61}Cu reactions were used. The excitation functions were measured in the E=3.67-3.83 MeV proton energy range. To determine the spins of the resonances, gamma angular distributions were measured. Partial widths for each resonance fragment were deduced and fine structure R-matrix analyses were carried out in the different channels. The inelastic spectroscopic factor was derived for the $1g^{9/2}$ IAS.

As to nuclear structure research, our aim is to study the mechanism of ^{3}He induced (tau,x), x:tau,tau,,p,d,t,alfa direct reactions at E=20-28 MeV bombarding energies on s-d shell collective nuclei and their structure by measuring the energy and angular distributions of the outgoing charged particles.

We are measuring the single-nucleon stripping and pick-up reactions, together with the elastic and inelastic scattering on ^{24}Mg target induced by the 28 MeV ^{3}He beam of the isochronous cyclotron of the Institute for Nuclear Research (Debrecen), with the aim of deducing the collective core excitation strengths and the spectroscopic amplitudes for final nuclei with (target xp(pi)/n(nu)) structure. From the (tau,tau) and (tau,tau,) data, applying the coupled channel approach one can evaluate the exact optical potential, free from structure effects due to the feedback to the elastic channel, and the collective strengths. A coupled reaction channel analysis of the reaction data, based on the strong coupling model taking into account the inelastic excitation in the entrance and exit channels, using realistic potentials and deformation parameter values, results in the nuclear structure data.

Measurement of the differential cross sections is carried out by a multi-channel high-resolution measuring system developed by our group. The system is based on the deltaE-E surface barrier detector telescope technique and allows us to measure the energy spectra of outgoing particles of different types for several angles simultaneously.

Materials Science

Substitution of diamagnetic Bi ions into the yttrium iron garnet ($Y_3Fe_5O_{12}$, YIG) increases the Faraday rotation of YIG from 200 up to 10^5 deg/cm, thus providing an exceptional material for magnetooptical applications. A model based on spin transfer between tetrahedral iron and dodecahedral bismuth has been proposed for describing the measured magnetization of BiIG. For checking the model, conversion-electron Mössbauer (CEM) measurements have been performed on epitaxial sputter-deposited BiIG, YIG and (Y,Bi)IG films. A YIG film, grown by liquid phase epitaxy, has been measured for comparison.

We found that the hyperfine field at the octahedral sites as measured for BiIG is H_a=498 kG, in good agreement with the YIG value. However, the field at the tetrahedral sites of BiIG is Hd=426 kG, greater by about 8% than the YIG value.

According to the molecular-field model, the only way of leaving the effective field of the octahedral sublattice unchanged is to change the Ndd intra-sublattice-molecular field coefficient, i.e. the magnitude of the intra-sublattice exchange interaction. Its decrease by about 10% could account for the measured value of the magnetization and hyperfine field.

Both positron annihilation and Mössbauer-effect studies were continued on the Y-Ba-Cu-O high-Tc compounds. Positron lifetime measurements have substantially contributed to the recognition of the role that "vacancies" (positron trapping centres) play in the technological quality of high-Tc samples. Systematic studies have also been initiated in order to clarify the conditions of stability of superconducting features even for thin layered samples.

Preference criteria established for surface studies using positron annihilation and Mössbauer methods have enabled us to improve the experimental performance by over an order of magnitude in the case of Depth-Selective Conversion Electron Mössbauer Spectroscopy (DCEMS). These improvements have made feasible the investigation of thin-layered sandwich structures including ^{57}Fe in atomic monolayer thickness (i.e. with respect to the study of diffusion and solid-state alloying processes, etc.). Application of the optimization considerations on the field of Time-Differential Mössbauer Emission Spectroscopy (TDMES) have also resulted not only in the realization of a spectrometer with unique features but also in the possibility of following fast relaxation processes and after-effects connected with the formation and decay of the Mössbauer-level in $^{57}Co/^{57}Fe$. A substantial part of above studies was carried out in cooperation with the Johannes Gutenberg Universität (Mainz) and the Kernforschungsanlage Jülich (KFA GmbH), Germany.

The Nuclear Analytics Group's work is mainly based on the Institute's 5 Mev Van de Graaff generator used for both ion implantation and analytical purposes. The analytical methods are Rutherford backscattering, elastic recoil detection, nuclear reaction analysis, channelling in crystalline samples, proton induced X-ray emission.

Three main topics were studied in the past two years. One of them was the "plasma-wall" interaction, i.e. the interaction between the active zone and the structural components of the thermonuclear power plants of the future. We investigated macroscopic surface deformations caused by ion implantation in model experiments, but joined the impurity transport investigations in the MT-1 tokamak, too. The second topic is related to the improvement of surface mechanical properties (friction, wear-resistance, hardness) as well as corrosion-resistance of metals by ion implantation. The third topic concerns damage and phase transitions caused by ion implantation and the elementary processes of ion - solid interactions in single crystals.

Additionally, we perform nuclear analysis as a service for domestic as well as foreign partners. For example, H depth distribution determination in neutron mirrors and amorphous Si and Si_3N_4 layers, measurements for the characterization of high T_c superconducting layers. We also deal with know-how transfer and provide advice for a number of institutes in, e.g., Lisbon, Leningrad and Algiers.

Plasma Physics

The main activity was concentrated around the MT-1 small research tokamak with major radius of $R_0 = 0.4$ m, minor radius $a = 0.09$ m, toroidal field $B_{t,max} = 2T$, discharge current $i_{max} = 35$ kA and the duration of the discharge $t = 9$ msec. This tokamak is dismounted during 1989 and its modernized version, the MT-1M tokamak was constructed. The main change in the construction is the substitution of the plasma stabilizing copper shell by active feedback control of the plasma position. At the same time the minor plasma radius could be increased to $a = 0.125$ m. The other features remain the same as that of the old machine. The new tokamak was put into operation in summer 1990.

1. Tokamak edge plasma physics

The investigation of the plasma density distribution in the plasma edge was continued using different experimental set-ups of the laser blow-off atomic beam.

The plasma density distribution is determined by observing the time function of the resonance line of the sodium atoms at different spatial observation position along the direction of propagation of a sodium atomic beam. The beam was created by blowing off a thin layer of sodium from the surface of a glass substrate using a Q-switched ruby laser pulse. The atomic beam propagated in the radial direction.

In earlier investigations a shortening of the light pulse of the resonance line versus the radial position of the observation was detected. This shortening was interpreted as the decrease of the density of the sodium atoms in the beam because of ionization of atoms by plasma electrons. The rate of ionization, consequently the decrease of sodium atom density i.e. the shortening of the observed light pulse is proportional to the plasma density. Therefore this plasma density can be determined by observing the shortening of the light pulse.

This measurement was perturbed by clusters of sodium formed frequently in the laser blow-off process. These clusters are atomized by the plasma electrons causing an increase of the number of atoms in the beam instead of the expected decrease due to ionization. Therefore the number of atoms in the beam was measured by observing the scattered intensity of the resonance light pulse of a tunable dye laser. The plasma density distribution can be calculated if the intensity of the resonance line of the atoms excited by the plasma electrons was also simultaneously observed in consecutive radial positions.

Choosing the fluence of the Q-switched ruby laser pulse at the surface of the thin sodium layer on the glass substrate with special care atomic beam without clusters can be produced. The plasma density distribution can be calculated on the basis of the observed pulse shortening and the density of sodium atoms measured by resonance fluorescence as well and the two results can be compared.

The good agreement of the two results gives confidence in the measurements. The second method using resonance fluorescence contain less interpretational difficulties but more experimental complication because of the use of an excess tunable dye laser.

The plasma density and temperature radial distributions were investigated also by Langmuir probes at different poloidal and toroidal positions. Determining the e-folding lengths from these distributions the cross field diffusion coefficients were determined and they were found to be approximately the same as the Bohm diffusion coefficient.

Different toroidal asymmetries were detected in the e-folding lengths of the density distributions and different observational positions using Mach probes. The measured plasma streaming velocity depends both on the radial position and the direction of the plasma current. The results could be interpreted as a transport of the rotation velocity of the plasma core into the scrape-off layer by friction forces.

The particle transport of the injected impurity atoms by laser blow-off method was investigated by using deposition probes. The probes were made of silicon and sodium atoms were injected. The sodium ions were implanted into the surface of the silicon sample by the scrape-off plasma after the particle transport process into the plasma core and back again into the scrape of layer. The radial distribution of the implanted sodium atom density which is proportional to the flux of particles was analyzed by ultra sensitive surface analytical method of resonance ionization mass spectrometry (RIMS) developed specially for the analysis of these tokamak samples. The sensitivity of the RIMS enables one to analyze samples exposed only to one tokamak discharge pulse in contrast to the old procedure of far lower sensitivity where the ions implanted by many tokamak shots are collected to be able to analyze the surface contamination density. The measured e-folding lengths of the radial distributions of the particle fluxes were about half of the e-folding lengths determined by averaging for many tokamak shots. The investigation of the cross diffusion using this ultra sensitive analytical method has to be continued to get more detailed results.

2. Magnetic island formation and disruptions

The time development of magnetic island formations and periodic minor disruptions are investigated by observing the time function of the intensity distribution of vacuum ultra violet (VUV) and soft X-ray radiation emitted by the plasma column by pinhole camera with micro channel plate detector with 12 anodes. The quantum energy of the observed radiation can be selected by using absorbing filters of different materials. The current of the anodes is proportional to the intensity of soft X-ray radiation emitted by the plasma and integrated along a chord. The different anodes correspond to the different chords. The current of the anodes are digitized simultaneously with a speed of maximum 1 MHz. The intensity

distribution is deconvolved from the result of the measurements using the principles of tomography and some simplifying assumptions. (Only horizontal asymmetry was allowed in deconvolved time function of the intensity distribution).

Magnetic islands are formed in the plasma by magnetic line reconnection as a result of some current perturbation. The new closed magnetic surfaces of the islands are the new isotropes of the plasma placed asymmetrically in the plasma column. The rotating plasma and the asymmetrical plasma temperature distribution causes a temporal modulation of the intensity of the radiation which can be clearly observed before the sudden drop in the intensity, i.e. before the disruption. The disruption is caused by merging the islands and the consecutive fast flow of energy along the field line out of the core of the plasma. The collapse of the plasma temperature is clearly seen with gradual recovery afterwards because of the joule heating the plasma by the current which also recovers after a sudden decrease in the disruption.

3. Infrared laser physics

Infrared lasers are often used in the diagnostics of the high temperature plasma. CO_2 lasers are used, for instance, for the measurement of the plasma turbulence by light scattering or for pumping far infrared Raman type laser used for plasma density measurement by interferometry. These lasers are usually not commercial lasers and therefore they are developed in laboratories interested in plasma physical investigations.

The molecular kinetic processes in the Raman type far infrared methanol laser pumped by CO_2 laser were investigated by using infrared - far infrared double resonance spectroscopy. The shape of the gain line of the methanol molecule produced by pumping with resonant infrared line are measured by detecting the function of the gain versus the frequency of the probing far infrared light generated by tunable far infrared laser. The shape of the gain line depends on the cross sections of the different collision processes among the molecules which cause the transition between the rotational and vibrational levels. The rate of the vibrational transitions which can be increased by adding buffer gas molecule determines basically the output power of the far infrared laser. Therefore the line shape of the gain was investigated by adding different buffer gases to the laser gas and a rate equation model is elaborated for the interpretation of the results of the spectroscopic measurements. We concluded that such a simple atom as helium works more effectively by increasing the vibrational relaxation better than a molecule as SF6 the internal degree of freedom of which is higher than that of helium. This observation is against the common expectation that a molecule of high internal degree of freedom has larger cross section for vibrational relaxation but it is in agreement with other observations that helium causes higher increase of the output power of the methanol laser than the SF_6 molecule.

4. Development of diagnostics

The laser blow-off atomic beam is used frequently for the measurement of the radial distribution of the plasma density and temperature by injecting atoms into the plasmas. The beam contains usually a mixture of atoms, clusters and ions of different velocity and the composition depends strongly on the physical parameters of the blow-off process, for instance, on the fluence of the laser beam, on the spot diameter of the light, the material composition of the thin film to be blown-off, and the thickness of the thin film. Therefore the composition of the laser blow-off beam has to be investigated specially taking the emphasis to the physical processes of the laser blow-off process.

The velocity of the atoms and neutral content of the laser blow off-beam were investigated using resonance fluorescence in an special, separate experimental set-up and the velocity of the beam and the path of the propagation of clusters are investigated on the tokamak itself using the same diagnostic set-up designed for the plasma density radial distribution measurements. The velocity depends on the one third power of the fluence of the blow-off laser beam and there is little clusters content of the beam at fluence higher than 20 joule/cm^2 for sodium.

Special device was developed and investigated for the application of resonance ionization spectroscopy (RIMS) for the analysis of samples exposed to the influence of plasmas in tokamak. The detected minimum surface density of sodium is in the order of 10^8 atom/cm^2 .

5. Plasma - wall interactions.

The work is mainly based on the Institute's 5 Mev Van de Graaff generator used for both ion implantation and analytical purposes.

Our analytical methods include:

- RBS (Rutherford Backscattering)
- RBS with special parameters (e.g. H^{41+} or N^{14+} ions used instead of He^{44+}, extra large sample tilt angles or energies, using resonances in the region of non-Rutherford cross-sections, etc.)
- ERD (Elastic Recoil Detection)
- NRA (Nuclear Reaction Analysis)
- Channeling used for the investigation of crystalline samples
- PIXE (Proton Induced X-ray Emission)

Our analytical methods are sensitive enough to detect any element of the periodic table present in concentrations of 10^{11} - 10^{15} atoms/cm^2 or 0.001-1 atomic % and to determine its depth distribution to a maximal depth of several μm with a maximal depth resolution of 5 nm. In case of single crystals, crystallographic characterization and lattice localization of impurity atoms down to an accuracy of even 0.01 nm (by using appropriate model calculations) are also possible.

With the above mentioned methods it is possible of effectively solving most problems encountered in this field of research, development or industry. Our activities must also include the continuous development of our experimental setup (scattering chambers, goniometers, data collecting and evaluating systems etc.) as well as the analytical methods. In the past two years our main developments connected to the plasma-wall interaction were:

- sample independent current measurement with a transmission Faraday cup.
- optimization of the ERD method

We investigated mainly the macroscopic surface deformations caused by ion implantation in model experiments. Our main results in this field are:

Using the NRA method developed for this special purpose, we successfully determined the distribution on collector probes of Li that was released into the plasma from erosion probes .

- The effect of implantation temperature and subsequent annealing on surface deformations caused by high dose MeV energy

He^{44+} and Ar^{40+} ion implantations in Al and Al alloys has been investigated in details. A close relation was found between the mechanical properties of the given materials and the critical noble gas concentrations that were needed for the onset of surface deformations. It was also pointed to that a subsequent annealing produces roughly the same effect for the investigated materials as rising the sample temperature to the same value during the implantation.

Extended research was devoted to the surface deformations caused by heavier noble gas implantation. The role of radiation assisted creeping was pointed at. A new type of surface deformations developing without a crack separating a layer from the bulk material was also observed.

It was justified by direct experiments that, in accordance with our model, the control parameter of the wavelength of periodic wave patterns appearing in ion implanted homogeneous samples is the thickness of the layer containing the implanted noble gas atoms.

It was pointed to that, in case of high ion energies, the crack causing the surface deformations appears at the maximum in the He depth distribution and no channels permeable for the gas develop at doses that are significantly lower than the critical one for onset of surface deformations.

Biophysics

The location and quantification of metal ions in certain bacterial metalloenzymes were extensively studied by combining particle induced X-ray emission (PIXE) with the biochemical separation technique called polyacrylamide gel electrophresis (PAGE). In the case of hydrogenase purified from Thiocapsa

roseopersicina not only the Fe/Ni ratio was successfully measured, but the PAGE-PIXE measurements clearly demonstrated that the iron atoms migrated together with the large subunit of the molecule while the nickels were apparently bound to the small one.

The PIXE target chamber was further improved in order to perform PIXE excited X-ray fluorescence experiments of special samples where selective excitation is necessary. The system was successfully used to determine trace amounts of Fe in pure Cu matrix.

The main intention of researches on natural and artificial information processing was to study the connections between the structure of (neural, computational and mental) networks and the performance of the processing. (i) Investigating self-organizing phenomena in the nervous system one question answered now partially is whether what kind of network structures can be considered as potential substrates of neural oscillators and even of chaotic generators. The May-Wigner theorem proved to be a useful tool for studying the connectivity-stability problem. (ii) Studies on artificial neural networks (mostly on Boltzmann machines) suggested that the connectivity pattern of the network might influence the overall behavior. Depending on the task to be solved, sparsing of the connections can increase or decrease the performance or even there are optimal random configurations. (iii) A class of the hierarchical neural networks was studied to link neural and mental models of semantic memory.

A multielectrode culture chamber was constructed for simultaneous monitoring of morphological and physiological characterization of neural development. Spontaneous activities have been recorded from both explant and primary monolayer cell cultures.

A general geometric optical method was presented to calculate the shape of the aspherical interface that eliminates spherical aberration of the doublet corneal lenses of some extincted trilobites. The refractive parameters of these fossil trilobite eyes was theoretically determined. The biomechanics of the roll technique of the beetle birch leaf roller (Deporaus betulae) was theoretically studied. On the basis of calculus of variations the optimal shape of the incisions cut by the beetle on the leaf sheet was determined. A new theory was presented for description of the shape of the Deporaus betulae's incisions, and the earlier wide-spread theory was refuted.

Theoretical Physics Research

Research in theoretical physics covers a wide spectrum of subjects ranging from the dynamics of nonrelativistic quantum systems to general relativity. The short summary below is intended only to give a sample of the interesting problems studied.

The transition between classical and quantum mechanics has been the subject of many papers. A recent study describing the stochastic modification of the Schroedinger equation shows how the classical properties of a system emerge in the quantum world.

In the simplest quantum system of two particles a strong coupling counterpart of the Born series has been developed in terms of modified WKB functions. The treatment can be extended to include repulsive and long-range Coulomb potentials.

Exact nonrelativistic multiparticle scattering theory has been applied to systems where the interplay between short and long-range interactions is the decisive factor. In the frame of the scattering theory formalism it was shown that the account of strong interaction effects in the muon catalysed fusion process may have an important effect on the muon "sticking probability". A treatment of the various interactions based on the two-potential formalism also shows that Coulomb effects on the motion of the muon may be responsible for the shortcomings of the "sudden" approximation.

Nuclear collision processes have been studied by various formalisms. In a recent study semi-microscopic nuclear hydrodynamics is used to describe nuclear density oscillations during collisions and has also been applied to low-energy oscillations of non-magic spherical nuclei.

Heavy ion collisions in the relativistic energy domain have been studied in a Budapest - Copenhagen - Wisconsin - Stony Brook collaboration. An analytic model of symmetry effects in jet fragmentation has been developed together with the SPACER model of relativistic heavy ion collisions.

There has also been a successful collaboration with the Dublin Institute for Advanced Studies that studied two dimensional conformal field theory and quantum groups. It particular, it was shown that two-dimensional Toda field theories and its generalizations can be naturally obtained as constrained Wess-Zumino-Witten models. A new quantum group appearing in the classical and quantum versions of the above models has also been discovered and described.

Different decay distributions for hyperon β-decays have also been calculated to order α in the Standard Model of elementary particle interactions. The distribution in terms of the electron energy, electron-antineutrino angle should be mentioned, which has not yet been calculated for an experimentally relevant situation, but offers high precision determination of the weak interaction couplings has also been obtained. The results show that the error caused by the use of inappropriate theoretical distributions in the experimental analysis is comparable with the experimental error in the best measurements of the β-decay of the Λ-hyperon.

Computing Services

Computer techniques in the Research Institute for Particle and Nuclear Physics (RMKI) are based on VAX compatible computers running under the VMS

operating system, viz. a TPA 11/520 and a TPA 11/530.

The program library contains:

- compilers for FORTRAN, VAX C, PASCAL
- interactive compilers and interpreters (e.g. BASIC, REDUCE)
- subroutine libraries (e.g. CERN library, IMSL library)
- program packages for graphic systems (e.g. GKS, GRAPHX)
- relational data base management system, VAX VMS/RDB.

These services are available from several types of terminals such as VT200 and VT340, as well as from a number of IBM compatible personal computers (about 40) connected to the system directly via an RS232 serial line or via an Ethernet based local area network using DECnet-DOS communication software.

The RMKI network, as part of the KFKI Ethernet/DECnet based network, was installed at the beginning of 1989 and is continuously under development. It provides:

- access to KFKI's central (BASF) computer,
- connection to the X.25 wide area packet switching network.

There is also a NOVELL/Arcnet based PC network integrated through te PC-NOVELL server into the RMKInet providing:

- access to VMS services for NOVELL wokstations
- access to NOVELL from PCs connected to Ethernet.

A special program package was developed to enable EARN mail to be used from DECnet nodes and NOVELL workstations too.

Our future activities include:

- increasing our computing capacity by using Transputers for parallel processing,
- establishing a computer link between RMKI and CERN.

Engineering Background

The technical background for the experimental physics research work is provided by the Technical Department. The results obtained in this activity have been widely used in other research institutes both in Hungary and abroad as well as in industry.

One important field of electronics development was tokamak instrumentation. The new system for plasma beam stabilization, built in connection with the reconstruction of the MT 1 tokamak, was successfully tested and installed.

For plasma diagnostics measurements a fast dual transient recorder was designed in Camac. The unit features 8 bit resolution, maximum 20 MHz sampling rate, flexible triggering possibility and 2 kbytes of fast buffer memory for each channel. The converted data can be read out either at a relatively slow rate via the Camac dataway or at a high speed via a front panel connector into a fast memory module.

CCD driver and amplifier circuits were designed for a 512 element light sensor array. The unit is used for detecting light spectra emitted by the tokamak plasma.

A high precision high voltage power supply was designed to deflect the beam of the Institute's Van de Graaff accelerator. The instrument provides symmetrical positive and negative output voltage, continuously adjustable between 0 V and 8 kV. The maximum load current is 1 mA.

For conversion electron detectors a charge sensitive preamplifier was built to be used in Mössbauer measurements.

In connection with the reconstruction of the Institute's research reactor a measuring system was constructed for automating neutron diffraction measurements. For the system a PC board was designed which controls various motors and switches and collects the measurement data. The operating software was written and the system installed in 1990.

With the support of the State Office for Technical Developement, a 16 channel fast D/A converter was developed in the VME system. The module features 12 bit resolution and 10 s settling time for LSB accuracy. The unit has 32 kword memory to store and to generate user-defined waveforms.

For medical purposes the development of a dose calibrator measuring the activity of various isotopes has begun. The prototype of the analog circuit converting the extremely low level signals of the ionization chamber (0.5 pA to 2 A) into pulse widths as well as the PC board receiving the converted signals was built and tested.

In cooperation with the Research Institute for Measurement and Computing Techniques a dual x-ray intensity digitizer system was designed for non-destructive material testing with the help of x-ray pulses. The system consists of two preamplifiers and a central unit performing A/D conversion and the transmission of the digitized data to the central computer.

The 4kMCA multichannel analyzer board was designed for use in IBM-PC compatible computers for high resolution gamma spectroscopy. Several units have been built and they are used in various measurements. The operating and the data evaluation software have been further developed.

Various kinds of flight-data recorders have been developed for aircraft. The on-board unit collects all the important engine and flight data into a high capacity semiconductor memory. After landing, the data are read into an IBM-PC compatible computer and the flight can be evaluated within minutes. The software provides graphic representation and archiving of the flight data.

A portable program store was developed for use with milling machines. The unit makes it possible for machine-independent milling programs to be written on IBM-PC compatible personal computers.

The other important field of development work was participation in various space research programs.

The Phobos spacecraft, launched in 1988, reached the vicinity of Mars in 1989. It carried several units that were developed with the participation of the Technical Department (HARP, LET, SLED, TAUS, SOWICOMS and the central computer of the small lander). As a consequence of a failure in the carrying spacecraft, radio connection with the probe was lost, but up to that time the instruments supplied a large quantity of valuable measurement data. The evaluation of the recorded information is in progress.

The design of the MICROSVIT image processing system was completed. It is due to form part of the on-board equipment of the MIR orbital station in 1991.

In 1994 and 1995 two radioastronomical space probes, SPECTRUM X-RAY GAMMA and RADIOASTRON will be launched from the Soviet Union to investigate far star-systems. The on-board central computer system of both spacecraft, together with the software to control the scientific instruments and the telemetry system, is being developed in our Technical Department.

In 1995 and 1996 two space probes, CASSINI and CRAF, will be launched by NASA to study the planet Saturn and the interplanetary region. Our institute is responsible for developing the ground support equipment and will take part in the development of the on-board software for the particle analyzer (CAPS) as well as for the magnetometer (MAG).

The next Russian missions to Mars are planned for 1994 and 1996. Among other experiments a balloon will be put into the atmosphere and a rover will be placed on the surface to explore a larger area of the planet. The Technical Department takes part in designing the hardware and software for the following measurements: plasma physical experiments MARIPROB, MAREMF, SLED-2 on the orbital unit; the on-board control and data acquisition computer of the balloon for studying the atmosphere of Mars; and the on-board computer for the rover - to guide it autonomously over the surface of the planet with the help of stereo picture pairs.

On the Minimum Uncertainty of Space-Time Geodesics

L. Diósi & B. Lukács

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Although various attempts at systematic quantization of space-time geometry ("gravitation") have been published, none is considered fully consistent or final. Nevertheless one can estimate the obligatory quantum unsharpness even without a consistent quantization method, by transplanting the Gedanken-experiment of Landau, Peierls [1], and of Bohr and Rosenfeld [2] to test quantum fluctuations (whatever they may be).

In this Gedankenexperiment our goal is to estimate the unavoidable quantum uncertainty of the metric tensor g_{ab} on a space-time net of worldlines as tight as possible. The measurement of the elements of g_{ab} can be reduced to that of proper time intervals by clocks moving along the world lines [3,4].

Here we confine ourselves to the simplest case of gravity being weak and the geometry being nearly static. Since it seems most unlikely that that large relative velocities of clocks would be advantageous, a system is involved in which where the motions are slow. Then the metric is Minkowskian except for $g_{00} = 1\text{-}2\Phi/c^2$ where Φ is the Newton potential ($\Phi << c^2$). For simplicity, we consider the case when the background is just the Minkowski metric, i.e. $<\Phi> \equiv 0$. The uncertainty Δg_{ab}, of the metric is contained in Φ:

$$\Delta g_{00} \sim \Phi/c^2 \tag{1}$$

Following Ref. 8 the correlation function of Φ reads

$$<\Phi(r,t)\Phi(0,0)> = \text{const.}*\hbar G r^{-1}\delta(t) \tag{2}$$

Attention is drawn here to two appealing features: first, c has been cancelled in eq. (2), i.e. the nonrelativistic Newton potential also possesses nonrelativistic unsharpness; second, the correlation function is of the white noise type implying statistical independence of fluctuations of Φ at different times. Equation. (2) conforms with an earlier result of Unruh [5] concerning the fluctuation of the curvature.

In Refs. 6 and 7 an alternative correlation function

$$<\Phi(r,t)\Phi(0,0) = \text{const.}*(\hbar G)^{2/3}c^2 r^{-1}* \\ *[r_+^{-1/3} + r_-^{-1/3}] \tag{3}$$

was proposed where $r_\pm = r \pm ct$. (Originally there the correlation for the Fourier coefficients of $\tau = -2\Phi/c^2$ was calculated.) It can be shown that eq. (3) corresponds to an optimal measurement of the length of a single world line.

was proposed where $r_{\pm} = r \pm ct$. (Originally there the correlation for the Fourier coefficients of $\tau = -2\Phi/c^2$ was calculated.) It can be shown that eq. (3) corresponds to an optimal measurement of the length of a single world line.

As demonstrated for example in Refs. [6-9], stochastic fluctuations of g_{ab} offer some natural mechanism for spontaneous reduction of wavefunctions. Comparing the correlation functions (2) and (3) one observes technical and quantitative differences between the corresponding reduction mechanisms as well.

Unless one finds a very sophisticated way of circumventing our "quantum relativistic" unsharpnesses, then eq. (1) gives the final uncertainty in determining the distances in a space-time net drawn to measure the space-time geometry. (Note that even then an individual geodesic line can be measured with higher accuracy, but it is not sufficient for determining g_{ab}.) If one represents the corresponding unsharpness of the geometry by appropriately adjusted stochastic fluctuations of the metric tensor then, in weak field approximation, the fluctuations of the nonrelativistic Newton potential are of white noise type and remain nonrelativistic. Both characteristics are rather attractive.

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Gravitational Multipole Moments

G. Fodor, Z. Perjés and C. Hoenselaers

J. Math.Phys. 2197 (1989)

All along the way to the discovery of the laws of relativistic physics, intuition has been guided to a large extent by detailed analysis of the known solutions of Einstein's equations. To give some examples, the physics of black holes, relativistic causality, the thermodynamics of the gravitational field have each benefited from the study of the spherically symmetric Schwarzschild space-time and the rotating Kerr solution. In the light of this, it is somwhat surprising that in many cases such important space-time configurations have been found by way of serendipity. Despite the fact that the relevant gravitational equations were well-known, researchers were unable to find the clues as to how to characterize the particular features of the desired solution. Suffice it to say that the Kerr space-time has been found as a result of a study of the geometry of shear-free light congruences; and that virtually its every particular feature (the stationarity, the event horizon, etc.) revealed itself whimsically as being a grace of chance.

In the seventies, several authors recognized independently that the generalization of the notion of multipole moments to curved spaces could be utilized to characterize the fields of localized matter surces. Geroch was first able to characterize static gravitational fields in terms of multipoles. A few years later his results were generalized by Hansen and Thorne to stationary sources. Later, Simon even succeeded in describing combined electromagnetic and gravitational sources. Although the multipole description of a general isolated source has eluded us up to now, the existing results have greatly helped us in obtaining many, physically significant conclusions.

The next task in working out the multipole techniques was to compute the multipole moments from the potentials of the fields. An obvious first target was the case of bodies rotating about their symmetry axes, since the gravitational fields of these are stationary. It is a well known fact that such gravitational fields are uniquely determined by the value of the complex gravitational potential on the symmetry axis. This property of the field is preserved by conformal maps. This makes it possible to relocate the multipole moments (quantities at spatial infinity) to the axis of symmetry. The evaluation of the first few multipole moments yielded the result that the values of the moments are equal to the expansion coefficients of the potential taken at spatial infinity. For a short while the researchers believed that this would hold true also for the higher moments, until Hauser showed the statement to be false for the $2 ^ 5$ gravitational moment. Thus it became desirable to develop an algorithm by means of which one could produce the multipole moments in terms of the gravitational potential.

In paper [1] we describe and utilize an algorithm for computing gravitational multipole moments; this algorithm appears to be more effective than any previous method, and has been implemented [by Gyula Fodor] as a code package in REDUCE. This package can generate multipole moments as high as the 2^{12}-th on the BASF computer of our institute in a matter of few minutes. Earlier computations by Hoenselaers provided up to the 2^7-th pole. Our results agree with his through the 2^7 pole. Paper [2] is devoted to an analysis of the structure of multipoles obtained. It is possible to recursively express the moments of some higher Tomimatsu-Sato space-times. However, there is no 'magic formula' available for an arbitrary body rotating about its axis of symmetry which would make the application of the algorithm superfluous.

The algorithm is extended in [3] to cover for Simon's electromagnetic moments, expressing them in terms of the expansion coefficients of the electromagnetic and gravitational potentials. The work was carried out on the IBM computer of the Max-Planck Institut fr Physik, and the paper presents the results up to the 2^5-th pole. Bonnor has pointed out that the field of the source in general relativity with a pure monopole and dipole moment is still unknown (The source of the monopole term is the rest mass, while the dipole moment is due to rotation). The Schwarzschild and the Reissner-Nordstrom space-times contain solely a monopole contribution with no dipole moment. The Kerr-Newman space-times have an infinite hierarchy of gravitational and electromagnetic moments. As a first application of the general-relativistic multipole moments, we investigate the pure monopole-dipole fields in paper [3]. Construction of the gravitational and electromagnetic potentials reveals surprising linear relations among these potentials. The significance of these relations is that they are likely to enable us to get the long sought-for relativistic monopole-dipole fields in the near future.

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Energy Densities, Target Fragmentation and Pion Correlations in Relativistic H. I. C. as Predicted by Spacer

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In the recent CERN heavy ion reactions of $^{16}O + {}^{197}Au$ and $^{32}S + {}^{197}Au$ at 200 AGeV laboratory energy the pure thermal QGP phase is not expected to appear, according to the SPACER estimate[1]. Even so, a 25-30% overall increase of the available (energy) densities is expected when changing to the ^{32}S projectile within our SPACER model. These values of our calculations are very much lower than the other estimates kpresented in the literature, because we have removed all the trivial and non-trivial kinematic effects which resulted in a seemingly enormous particle number densities or energy densities [2].

We have appended SPACER with an analytical Boltzmann gas model to describe the momentum distribution of the disintegrated target "spectator" nucleons [3]. Our results agree with the recent WA80 [4], EMU01 [5] and E802 [6] data, although the much more sophisticated MCMF [7] and FRITIOF [8] models fail to do so. Our model also predicts a scaling in the target fragmentation regime, which scaling was observed experimentally form $p + A$ to $A + B$ reactions. We have interpreted the β parameter of the scaling distribution in terms of the temperature and the average longitudinal velocity of the heated spectator matter [9].

The exponential shape of the two-pion correlation function $C(Q_l)$ was observed by the NA35 collaboration [10]. This shape was predicted by the SPACER simulation, with intercept $C(0)$ close to unity [11]. The experimental volue for this quantity was compatible with the SPACER prediction, however our model systematically underestimated the NA35 source sizes. This could be due to the neglection of the rescattering of the secondary particles or the appearance of a phase transition. The correlations between spacetime and momentum space make the relation between the two-pion correlation function and the spacetime characteristics of the source non-trivial. A consequence of these correlations was used to interpretate the the AFS Bose-Einstein correlation functions [12].

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Models for Universal Reduction of Macroscopic Quantum Fluctuations

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If quantum mechanics were universal then macroscopic bodies would, in principle, exhibit macroscopic quantum fluctuations (MQF) in their positions, orientations, densities, etc.; however, such MQF's have not yet been observed. The absence of MQF may either be a consequence of inevitable interactions with the actual surrounding[1-3] or, alternatively, it is universal and stems from a new mechanism[4-9]

This paper adopts the latter hypothesis and applies gravitational measures[8,9] to reduce MQF. We assume the nonrelativistic mass density operator f(r) to be continuously observed. Such a continuous quantum measurement, as shown by the author[10], modifies the usual unitary equation of motion. The pure quantum state $\rho = \phi\phi^+$ of a given system satisfies the following quantum-stochastic differential equation (QSDE):

$$d\rho = L[\rho]dt + \int \{f(r) - \langle f(r) \rangle, \rho\} d\xi(r) dr \qquad (1)$$

where

$$L[...] = -i[H,...] - \kappa \iint [f(r_1),[f(r_2),...]] r_{12}^{-1} \, dr_1 \, dr_2 \qquad (2)$$

is the Liouville operator, and $\xi(r)$ is a homogeneous Wiener process with spatial correlation $1/2\kappa G/r$. G denotes Newton's gravitational constant, κ is a numerical coefficient of order 1. The QSDE (1) preserves the pure state property

$$\rho^2 = \rho$$

The second terms on the RHS's of Eq.(1) and Eq.(2) are responsible for the proper damping of MQF. It is easily seen that violation of ordinary quantum mechanics (QM) depends primarily first of all, on the gravitational energies represented by the given state of the system. In the case of microsystems we thus expect that violation of QM can be neglected. For macroobjects, on the other hand, genuine classical properties (e.g. trajectories) will emerge.

Let us discuss a typical example of reduction of MQF. Consider a macroscopic (or, maybe, mesoscopic) system which is assumed to be, at time $t = 0$, in the superposition

$$\Psi = \sum_A c_A \Phi_A, \qquad \Sigma |c_A|^2 = 1 \tag{3}$$

of a certain number of normalized states Φ_A ($A = 1,2,....$). For example, let Φ_A represent the localized state belonging A^{th} to the A separate position of a pointer of a given measuring device. Introduce, furthermore, the probability weight $p_A = |c_A|^2$ for each pointer position $A = 1,2,...$ respectively.

By neglecting the Hamiltonian term, and making some simple assumptions, our central equations (Eqs.(1,2)) will lead to a closed system of equations for the coefficients $c_A(t)$ of the superposition (3). The probabilities $\{p_A\}$ will perform Wiener random walks of correlations

$$dp_A dp_B = 2\kappa |U| dt\, p_A p_B [\delta_{AB} - p_A - p_B + \sum_R p_R^2], \tag{4}$$

where U is the classical Newtonian gravitational self-energy of the pointer.

The above result is mathematically equivalent to Gisin's phenomenological "continuous reduction model" [5]. As can be shown, each probability $p_A(t)$ will approach zero for times $t \gg h/|U|$, except for a single one (say, the K^{th}) which becomes unity. The superposition (3) will then be reduced to one of the component states, in our case, to Φ_K. In addition, the expectation value of $p_K(t)$ is constant ($|c_K(0)|^2$) all the time, thus the K^{th} pointer position is realized with the proper quantum-mechanical probability.

The classical gravitational self-energy U of a typical macroscopic object (e.g. a pointer) of mass $M \sim 1$ g, of size $R \sim 1$ cm is about $GM^2/R \sim 10^{-8}$ erg. The superposition of distant pointer states would be reduced after a period of the order $h/10^{-8}$ erg $\sim 10^{-19}$ s. This period is much shorter than the time scale of any nonrelativistic quantum evolution, consequently, the above macroscopic distant superposition could not even come into existence. Causality forbids formation of a configuration of 1 cm within 10^{-19} s. Needless to say, neglect of the Hamiltonian motion during the reduction period has been justified as well.

For lighter objects, the reduction time becomes more realistic. If, e.g., $R \sim 10^{-2}$ cm, and $M \sim 10^{-6}$ g, then $GM^2/R \sim 10^{-18}$ erg and the reduction time is of the order $h/10^{-18}$ erg $\sim 10^{-9}$ s.

In our theory a definite gravitational measure has been postulated for the reduction of the MQF of mass densities and only a single dimensionless number (κ) had to be fixed by hand. This kind of modification of the ordinary dynamics seems to eliminate certain paradoxical features of QM and makes a unified description of the micro- and macroworld possible. In particular, formation of distant superpositions of massive objects is practically forbidden.

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Symmetries in the Phoneme Recognition

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If speech recognition can be reduced to recognition of separate phonemes (which seems true at least approximately for some languages), then, in a given community of speakers, a set of acceptance functionals $p_\alpha(f)$ must exist, where f is the (generally complex valued) Fourier transform of a sound and $p\tau$ a is the probability of acceptance as a representation of the α^{th} phoneme of the phoneme system of the language. In an earlier paper [1] we listed the essential properties of this functional mainly for vowels where, due to the Ohm-Helmholtz Law f can be regarded as real. If the functionals p_α were known, automatic speech recognition would be solved, because the frequency distribution $f(\nu)$ can easily be measured by physical methods.

The present paper deals with the symmetries of the functionals $p_\alpha(f)$, first in general, second especially for Hungarian. A symmetry is a transformation Tf of f so that

$$p_\alpha(Tf) = p_\alpha(f) \quad \text{for all } \alpha \tag{1}$$

Such symmetries obviously exist in every language because there are always such degrees of freedom of the pronunciation which do not alter the phoneme. The three simplest possibilities of such a symmetry are neutral amplification, frequency rescaling, and change of intonation.

Neutral amplification is the transformation

$$T(q)f(x) = e^q f(x) \tag{2}$$

This connects sounds heard at different distances, so it must be at least an approximate symmetry.

Frequency rescaling is given by:

$$T(\alpha)f(x) = f(e^\alpha x) \tag{3}$$

This is an approximate symmetry if all the body sizes (including the size of the vocal channel) of the speakers of the community are proportional to height, and if they form the sounds with the same motions of the vocal channel. The symmetry is suggested by the fact that a recorded speech remains clearly intelligible if played at different speeds.

Change of intonation is the following transformation. Consider a given phoneme. Its pronunciation may carry two items of information: the phoneme itself and the value of an intonation parameter τ whose values may express emphasis, question, etc. Then there must exist a second functional Θ

$$\tau = \Theta(f) \tag{4}$$

and then, since the change of intonation should not disturb the communication process, there must exist a symmetry

$$f \in \{f(x;\tau)\}, \quad \tau = \Theta(f(x;\tau)) \tag{5}$$

$$T(\tau')f(x;\tau) = f(x;\ \Theta(f(x;\tau)) + \tau') \tag{6}$$

No clear suggestion exists for the forms of Θ or T. However, there seems to be a factorization in the formation of the final f(x) in resonance processes. Therefore

$$T(\tau')f(x;\tau) \sim \sigma(x;\Theta+\tau')\sigma^{-1}(x;\Theta)f(x;\tau) \tag{7}$$

with the compatibility constraint

$$\Theta(f)+\tau = \Theta\{s(\Theta(f)+\tau)f\sigma^{-1}(\Theta(f))\} \tag{8}$$

Now we show that the forms of $T(\tau')$ and are prescribed by the mathematical structure if these three symmetries and only these hold. Then the algebra of the

commutators must be closed. The neutral amplification commutes with both other transformations. There remains only one commutator to be evaluated. For infinitesimal transformations

$$\Theta\ \{f(e^{\alpha}\ x) = \Theta\{f(x)\} + \alpha ß\{f(x)\} + o(\alpha^2), \tag{9}$$

whence the commutator gets for infinitesimal values of the form

$$\begin{aligned}
&\{T(\tau')T(\tau) - T(\tau)T(\tau')\}f \ = \\
&\quad = \alpha\tau'\{ß(f)\partial\mu(x,\Theta(f))/\partial\tau \ - \\
&\qquad x\partial\mu(x,\Theta(f))/\partial x\}f + o(\alpha^3, \alpha^2\tau', \ldots) = \\
&\quad = Af + Bx\partial df/\partial x + Cß(x,\Theta(f))f, \\
&\mu \equiv \partial\sigma(x,\tau)/\partial\tau,
\end{aligned} \tag{10}$$

where A, B and C are free structure constants. Hence

$$B = 0, \quad ß = ß(\delta) \tag{11}$$

and we are left with remains a differential equation having four different solutions the simplest one of which has the form

$$ß = 0, \quad \mu = \Phi(\Theta) - A\ln(x), \tag{12}$$

where the function Φ is free.

Observations show that the vocal chords generate a roughly saw-toothed amplitude function of the primordial sound with an opening motion for time t_1 and closing one for t_2. If $t_1/t_2 = \text{const.}$, then this leads to

$$\sigma = u(x)v(\tau_2 x). \tag{13}$$

Obviously $\tau = \tau(\tau_2)$. Now, with a function of form (11) the constraint equation (8) is fulfilled. In addition, for $t_1 << t_2$ (which conforms with observation) is well populated even at high frequencies. Therefore, the observed motion of the vocal chords seems to be an adaptation to the necessity of different intonations.

However, if the frequency rescaling (3) is a symmetry then the acceptance regions on the two-formant plane (ν_1,ν_2) form radial lines (or, if the symmetry is approximate, elongated radial ellipses). English data indeed show elongated and roughly radial regions [2], but the Hungarian ones [3] suggest vertical ones. In addition, in Hungarian there is a tendency for two or three phonemes to be located vertically on the two-formant plane. To see this, take the data of Ref. 3, and perform a Gaussian fit for the distributions of the formants of each phoneme on the two-formant plane. Then the confidence region of a phoneme is elliptic. Now, we get 18 such ellipses (9 for male and again 9 for female speakers). The orientations

of the major axes differ from vertical only in 2 cases at 2σ level. So the regions themselves tend to be vertical. Now, Fig. 1 shows the locations on the two-formant plane, together with the confidence interval for *first* formants. One can note two facts:

1) As expected, the *second* formant frequencies seriously differ for male and female speakers; however the *first* ones do not.

2) Within the confidence intervals the *first* formant frequencies overlap in the groups {i,ü,u}, {é,ö,o} and {e,a}. These are just the groups grammatically defined by the rule of vowel harmony.

This doubly vertical structure clearly disproves the existence of a frequency rescaling symmetry *in Hungarian*. This fact may be surprising; remember that this symmetry was made plausible via correlated variations of body sizes. So the result may be a sign of still uninvestigated anthropological or sociological phenomena; here we would only mention that Lotz found a similar vertical structure for the *average* formant frequencies in Turkish [4]. Anyway, one can conclude that in Hungarian no constraint has been obtained for the spectral function of the vocal chords because the remaining two symmetries commute, so the algebra is always closed. Therefore the Hungarian phonetic system leaves more freedom for intonation than does the English one.

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Meson Capture and Transfer in Hydrogen Containing Systems

D. Horváth

A series of experiments was performed at TRIUMF (Vancouver, Canada) to study the elementary atomic processes following the slowing-down and Coulomb capture of muons and pions in hydrogen isotopes and hydrogen-containing molecules.

Based on a method originally developed in Dubna, USSR, we used pion capture in hydrogen to study the electron distribution in hydrogen-containing molecules (pion chemistry). The capture of a pion by a proton was identified using the charge-exchange reaction $p\pi^- \rightarrow n\pi^0$. The coincident photons from π^0 decay were detected by TRIUMF's two large NaI(Tl) spectrometers. We measured the capture probability of stopped π^- mesons in the nuclei of hydrogen atoms, chemically bound in molecules of some simple hydrides, acid anhydrides, and sugar isomers [1]. The results suggest a correlation between pion capture in hydrogen and the melting point of sugar isomers. The pion capture probability in acid anhydrides is fairly well described by a simple atomic model in which this probability dramatically increases when the hydrogen atom is separated from the strongly electronegative C_2O_3 group. Both effects are consistent with a correlation between pion capture and electron density in hydrogen atoms.

Recently, the interpretation of pion chemistry results became somewhat contradictory, the role of collision processes and the mesic molecule as an intermediate state were questioned. On the basis of the available experimental data, we have shown [2] that - in spite of its rather rough approximations - it is Ponomarev's model of large mesic molecules that gives the best description of the processes involved in pion capture by hydrogen bound in molecules. Both of the new approaches, Daniel's transfer model and Jackson's Surrey model are inconsistent with the experimental evidence.

Negative pions were stopped in gaseous mixtures of hydrogen and deuterium and the $p\pi^- + d \rightarrow d\pi^- + p$ transfer process was studied as a function of deuterium concentration C [3]. The concentration dependence of the transfer rate was fitted by a two-parameter phenomenological model. For $C \rightarrow \infty$ (32 $\pm$ 3) per cent of the pions undergo transfer. The fitted parameters reflect the ratio of pion capture to pion transfer in collisions of pionic hydrogen with protons or deuterons. No pressure dependence of pion transfer was observed.

An interesting branch of the physics of exotic atoms is the study of muon catalysed fusion. We have compared the capture of negative muons in gaseous $H_2 + D_2$ and HD looking for molecular and collision effects similar to those found in pion capture. We have used the fusion photon from $p + d \rightarrow {}^3He$ + gamma as a monitor and found twice as many photons from $H_2 + D_2$ as from HD [4], in contradiction with theoretical expectations based on non-resonant formation of $pd\mu$ muonic molecules. Moreover, an unexpected temperature dependence was observed in the fusion gamma-yield from $H_2 + D_2$: at 22 K it is three times higher than at room temperature. Both phenomena contradict the accepted theoretical pictures of the muonic processes in hydrogen isotopes. In order to exclude possible experimental errors the measurements were repeated with a new target and they gave the same results.

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Description of the Scaled Moments for the Nondiffractive pp and $p\bar{p}$ Interactions in the CMS Energy Range 10 9000 GEV

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Physics Letters B228, 159 (1989)

Based on our phenomenological studies [1] we propose a distribution function for multiplicities of different processes in accordance with the stochastic number evolution [2]. The same function can also be extracted from a generalized geometrical model [3] in the impact parameter representation. This function proved to be very successful in analyzing the multiplicity distributions of $e^+ e^-$ annihilation into hadrons [3]. In addition, our formula gives a general description of inelastic and nondiffractive multiplicity distributions in pp collisions at 250, 360 and 800 GeV energies [4], and describes [1] the inelastic scaled moments for pp interactions at Serpukhov, FNAL and ISR energies too.

In this paper we show that this formula is reasonable to describe the available [5], [6] nondiffractive data between $\sqrt{s} = 10$ and 900 GeV, and we predict a multiplicity distribution for $\sqrt{s} = 1.8$ TeV. The proposed multiplicity distribution is the following:

$$P_n = \frac{2m}{\langle n \rangle \Gamma(A_m)} F^{A_m}(A_m) \left(\frac{n}{\langle n \rangle}\right)^{mA_m - 1} \exp\left[-F(A_m)\left(\frac{n}{\langle n \rangle}\right)^m\right], \quad (1)$$

where

$$F(A_m) = \frac{\Gamma^m(A_m + 1/m)}{\Gamma^m(A_m)}, \quad (2)$$

and m is a real positive number, which is independent of energy. The scaled moments are as follows:

$$c_L \equiv \frac{\langle n^L \rangle}{\langle n \rangle^L} = \frac{\Gamma(A_m + L/m)}{\Gamma^L(A_m + 1/m)} \Gamma^{L-1}(A_m). \quad (3)$$

One can see that

$$\langle n \rangle P_n \equiv \Psi\left(z = n/\langle n \rangle, s\right) \qquad (4)$$

has KNO scaling behaviour $(\Psi)(z,s) \rightarrow \Psi(z)$ or c_L = constant for every L, when $s \rightarrow \infty$) if A_m tends to a constant value when the energy goes to infinity. Thus A_m is the scaling violation parameter.

The analytical form of formula (1) was originally developed by the generalization [1], [7], [8] of the constraint method [9]. It is remarkable that the stochastic number evolution [2] is also in accordance [4] with formula (1). Our main purpose in this paper is to check formula (3). We emphasize that the scaled moments are very attractive because these quantities are fairly insensitive to the acceptancies in the energy range 200-900 GeV [5]. The scaled multiplicity moments for the nondiffractive part of the inelastic interactions in the 10-900 GeV energy range are well parametrized with a negative binomial distribution having two energy dependent parameters, $\langle n \rangle$ and k [5], [6]. On the other hand, we have only one parameter, A, depending on the energy because at each energy we used $m = 1.25$ obtained in ref. [4] for non-diffractive case. We should like to note that m means the order of nonlinearity [4] in the picture of stochastic number evolution. Our procedure is the following. Taking c_2 from experiment at a given energy, we can determine A by inverting (3) for $L = 2$ numerically, and substituting A into formula (3) we can compare the calculated moments with the observed c_L's for $L > 2$.

The procedure described above gives the results collected in Table 1 for Sp$\bar{p}$S energies [5], [6]. In each of the columns of the scaled moments c_2 the first values are calculated from (3), the next ones are the experimental values. We can see that all calculated higher moments c_L ($L > 2$) are in excellent agreement with the observed values of c_L 's for pp and $p\bar{p}$ interactions [5], [6].

The energy dependence of parameters $\langle n \rangle$ and A is on an empirical level. Nevertheless, good zero parameter empirical description is presented in ref. [7] for inelastic pp interactions in the 50-2100 GeV energy range. The trend of parameter A for the nondiffractive case is more sophisticated because A is decreasing at the published Sp$\bar{p}$S energies. Nevertheless we can adopt a simple parametrization for $\langle n \rangle$ ($\langle n \rangle = -7 + 7.2\, s^{0.127}$) published in ref. [5]. Our parametrization for A, $A = Cs^{R/2}$ (where $C = 5.08 \pm 0.47$, $R = -0.133 \pm 0.026$), also yields a reasonable fit to the data ($\chi^2/NF = 12.2 = 9$).

We can apply our model to 1.8 TeV energy with the assumption [10] that

$$\frac{\hat{n}}{\langle n \rangle} = \frac{28}{41},$$

where n stands for the most probable volue, and we can easily calculate the parameter A, which proved to be $A = 1.96$. In particular, we present in Table 2 the results for $p\bar{p}$ interactions at $\sqrt{s} = 1.8$ TeV. The predicted c_L 's are similar to those predicted in ref. [11]. It is interesting that with the above assumption we can predict not only the higher scaled moments but the multiplicity distribution too (using $\langle n \rangle = 41$, $A = 1.96$ and $m = 1.25$).

Our prediction is in good agreement with the above mentioned parametrization of $\langle n \rangle$ and A ($\langle n \rangle = 41.3$ and $A = 1.87$ at 1.8 TeV).

In conclusion we can state that the proposed distribution (1) gives a good description of the published nondiffractive scaled moments in the whole of this large energy region. We eagerly wait for the data from Tevatron to compare our predicted multiplicity distribution with the experimental results at $\sqrt{s} = 1.8$ TeV.

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$\sqrt{s}$ (GeV)	A	c_2	c_3	c_4	c_5
200	2.48	1.26 1.26±0.03	1.90 1.91±0.12	3.30 3.3±0.3	3.54 6.6±0.9
540	2.08	1.31 1.31±0.03	2.10 2.12±0.11	3.95 4.1±0.3	8.51 8.8±1.0
900	1.90	1.34 1.34±0.03	2.22 2.22±0.13	4.37 4.3±0.4	9.87 9.3±1.1

Table 1

$\sqrt{s}$ (GeV)	A	c_2	c_3	c_4	c_5
1800	1.96	1.33	2.18	4.22	9.37

Table 2

Calculation of the Pion Decay Constant and Quark Condensate in Chiral QCD.

V. Sh. Gogohia and Gy. Kluge

Some basic physical parameters of chiral QCD have been calculated within a new non-perturbative, dynamical quark propagator model. We proposed a general, gauge-invariant and non-perturbative approach within the closed set of Schwinger-Dyson (SD) equations and the corresponding Slavnov-Taylor (ST) identities for Green's functions. The central role is played by the quark propagator satisfying some necessary conditions. Using our non-perturbative solution for the quark propagator some basic chiral QCD parameters, such as the pion decay constant, the quark condensate and dynamical (nonperturbative) quark mass have been calculated numerically, in a self-consistent way. We have shown that the main contribution to the values of these parameters comes from the large distances, while the contributions from short and intermediate distances can only be treated as perturbative corrections.

In current algebra the pion decay constant F_π is defined as

$$\langle 0|J^i{}_{5\mu}(0)|\pi^i(q)\rangle = iF_\pi q_\mu \delta^{ij} \qquad (1)$$

(F_π = 93.3 MeV normalization is used). Clearly, eq. (1) can be written in terms of pion-quark-antiquark proper vertex and quark propagators as

$$iF_\pi q_\mu \delta^{ij} = \int \frac{d^4p}{(2\pi)^4} Tr\left\{\left(\frac{\lambda^i}{2}\right)\gamma_5\gamma_\mu S(p+q)G_5^j(p+q,p)S(p)\right\} \qquad (2)$$

The trace is over the Dirac and colour indices. To get expressions for F_π one has to differentiate both sides of eq. (2) with respect to external momentum q_ν and set then $q_\nu = 0$.

The Bethe - Salpeter pion wave function G5(p + q,p) was obtained from the non-singlet, flavour, axial-vector Ward identity in the chiral limit. After some algebraic manipulations on the quark propagator solution we obtained the following expression of pion decay constant in terms of parameters which have a clear physical meaning:

$$F^2 = \frac{3}{8\pi^2} k_0^2 z_0^{-1} \int_0^{z_0} dz \, \frac{zB^2(z_0,z)}{\{zg^2(z)) + B^2(z_0,z)\}}, \qquad (3)$$

where

$$g(z) = z^{-2}(\exp(-z) - 1 + z) \tag{4}$$

and

$$B^2(z_0, z) = 3\exp(-2z)\int_z^{z_0} \exp(2z')g^2(z')\,dz'. \tag{5}$$

The order parameter of the DCSB-quark condensate can be expressed in terms of the quark propagator scalar function $B(p^2)$.

$$\langle\bar{q}q\rangle_0 = -\frac{3}{4\pi^2}k_0^3 z_0^{-3/2}\int_0^{z_0} dz\, zB(z_0, z), \tag{6}$$

where for light quarks in the chiral limit

$$\langle\bar{q}q\rangle_0 \equiv \langle 0|\bar{u}u|0\rangle_0 = \langle 0|\bar{d}d|0\rangle_0 = \langle 0|\bar{s}s|0\rangle_0,$$

by definition, and $B(z_0,z)$ is again given by eq.(5). The dynamical quark mass M reads as

$$M = k_0\left\{z_0 B^2(z_0, 0)\right\}^{-1/2}, \tag{7}$$

where $B^2(z_0, 0)$ is given by (5) at zero point.

Momentum k_0 is a free parameter of our approach while the dimensionless auxiliary parameter z_0 can be determined from the dynamical quark mass M. The exact value of M is not known, so varying M and k_0 numerically one can calculate the pion decay constant F and the quark condensate, respectively. The pion decay constant in the chiral limit F cannot exceed its physical value $F \leq F = 93.3\ MeV$.

Since the physical value for the quark condensate is not known we assume, in agreement with other estimates (see below), that the quark condensate (6) in the chiral limit satisfies a probable upper boundary value condition

$$\langle\bar{q}q\rangle_0^{1/3} \leq -200\ MeV.$$

The numerical results of our calculations are shown in Figs. 1 and 2, where the F and $\langle\bar{q}q\rangle_0^{1/3}$ values are drawn for the most reasonable region of the dynamical quark mass, viz. $200\ MeV \leq M \leq 400\ MeV$.

From Figs. 1 and 2 it follows that momentum k_0 always satisfies the upper and the lower boundary value conditions $k_0 \leq 775\ MeV$ and $k_0 \geq 635\ MeV$, respectively. Evidently, momentum k_0 is a momentum which separates the nonperturbative phase (region) from the perturbative phase (region), so in the region obtained for k_0 the nonperturbative effects begin to play a dominant role. This region determines a scale at which confinement occurs. This confinement region for k_0 (in the chiral limit) was found to be $635\ MeV \leq \Lambda_c \leq 775\ MeV$. The pion decay constant and the quark condensate were found to be

$$71.5\ MeV \leq F \leq 93.3\ MeV$$

and

$$-256\ MeV \leq \langle\bar{q}q\rangle_0^{1/3} \leq -200\ MeV,$$

respectively. The confinement scale Λ_c determines a scale of nonperturbative dynamics in QCD. To establish the exact value of Λ_c is the same as establishing the exact value of the dynamical quark mass within our dynamical quark propagator method.

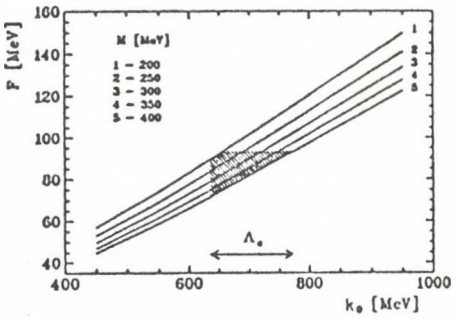

Fig.1. Pion decay constant F as a function of k_0, Λ_c is a confinement scale.

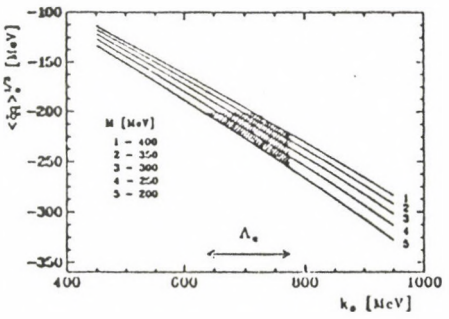

Fig.2. Quark condensate $\langle qq\rangle_o^{1/3}$ as a function of k_o, $\Lambda_c$is a confinement scale.

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KFKI RESEARCH INSTITUTE FOR SOLID STATE PHYSICS (SZFKI)

This Institute is devoted to basic and applied research in the areas of solid state physics and optics. Both areas have traditions dating back to the foundation of the research centre KFKI in 1950. The total staff consists of 160 people out of which there are 100 scientists and engineers.

In the last two years, research has covered the following main fields:

- solid state theory and statistical physics
- charge density waves and high temperature superconductors
- non equilibrium alloys
- liquid crystals
- materials science
- neutron physics
- amorphous semiconductors
- laser physics
- laser applications.

Here a short general review is given on recent progress in these fields; this is followed by a selection of important topics. The account is closed by the list of publications for the given period numbering about three hundred items.

Solid State Theory and Statistical Physics

During our investigations of the low-dimensional magnetic and electronic systems we determined the excitation spectra of the exactly soluble, finite-size Hubbard chains by applying the Bethe ansatz. On the other hand, for spin chains

with integer spin, we made use of a model with general couplings; by varying a parameter we were able to examine the modification of the energy spectrum around some integrable points.

With regard to the generalization of the two-band Hubbard model by means of the renormalization group theory we investigated a model of the two-band interacting electron gas with light and heavy fermions. Moreover, for the heavy fermion problem we also studied the variational solutions of the periodic Anderson model.

With the help of a partially non-perturbative path integral method, we described the dissipative motion of heavy particles in a fermion heat bath in the case of strong dissipation.

The theory of high T_c superconductors, especially the unusual properties of their normal state, was studied extensively. A two band model has led to the measured Hall effect and the plasma frequency in $La_{2-x}CuO_4$. In order to explain properties such as reflectivity, resistivity, photoemission, etc. of the normal state a microscopic theory has been presented.

The pinning mechanism of spin density waves in quasi-one- -dimensional materials has been examined with the conclusion justified by recent measurements that Friedel oscillations around non-magnetic impurities hinder their movement.

The structure and electronic states of quasi-periodic systems were studied introducing a reciprocal-space version of the KKR band theory. Numerical results have been presented for a Fibonacci chain of square well potentials.

In the course of our research on the interaction of strong electromagnetic fields with matter, we have developed non-perturbative methods to treat various non-linear processes (e.g. microwave ionization of Rydberg atoms, high harmonic production in strong laser fields).

Investigations in statistical physics have been concentrated on phase transitions in complex dynamic systems. The statistical properties of the chaotic state of non-linear dynamical systems have been studied. The singularities of the Renyi information have been linked with phase transition-like phenomena whereby new phenomena of such kind have been found. When investigating the cellular automata versions of the kinetic Ising models, a model belonging to a novel universality class was found ($Z=1$). A quantitative connection between domain growth and critical dynamical scaling behaviour has been pointed out for certain one-dimensional kinetic Ising cellular automata models.

Experimental Studies of Charge-density-wave Dynamics

In 1989-90 we continued to investigate the field- and frequency dependent excitations of charge-density-waves (CDW) and extended our research in quasi-one-dimensional conducting crystals to similar spin-density-wave (SDW) systems.

The most characteristic feature of the CDW response is the non-linear d.c. conductivity. The interaction with impurities pins the CDW to the underlying lattice, but above a well defined threshold field the condensate can be set into motion resulting in excess current. The CDW current has an alternating component whose frequency is proportional to the current density. We simultaneously detected the oscillatory term at several points along the crystal. Our results gave direct evidence of the propagation of CDW vortices.

In SDW materials we established the relation between the frequency dependent and the non-linear response. Our real time relaxation experiments were the first to reveal internal SDW excitations.

High Temperature Superconductivity

A crystal field analysis of the electron spin resonance spectra of Gd substituted for Y in $YBa_2Cu_3O_y$ was given. Direct evidence for the local order of oxygen has been found in nearly the full range of $6.0 < y \leq 7.0$.

Non-equilibrium Alloys

Our research is aimed at improving our understanding of the atomic and electronic structure of the non-equilibrium alloys. We have extended our previous Mössbauer spectroscopy studies to metalloid-free melt-quenched transition metal-transition metal-alloys. The local structure of the (stable and metastable) intermetallic compounds has been found to approach closely the short range order of the non-crystalline alloys even in this new class of materials. Systematic study of the temperature dependence of hyperfine field distributions has shown that it is essential to take into account the correlation between the magnetic moment and the exchange interaction distributions in order to be able to understand the magnetic properties of any kind of material (including intermetallic compounds and metallic glasses) in which the transition metals are located in non-uniform local environments.

Our studies were also extended to comparing the atomic and electronic structure of identical composition non-equilibrium alloys produced by melt quenching and by other methods, including ultra high vacuum evaporation, laser

surface melting and mechanical alloying. We have succeeded in preparing non-equilibrium alloys by laser-melting in many different systems. Fe-B amorphous alloys prepared by this technique made it possible to verify that the distribution of atomic environments in evaporated thin layers is significantly broader than that of glasses solidified from the melt. The mathematical model of melt solidification was also improved by taking into account the surface heat transfer. Our studies indicate that non-equilibrium alloys of different degrees of excess free volume are produced by the different techniques and this is reflected by their different magnetic properties.

Liquid Crystals

The investigation of ferroelectric liquid crystals was continued. Compounds exhibiting ferroelectric properties were synthesized, their impurity content was reduced and checked. Binary and ternary mixtures were prepared in order to extend the chiral smectic C* temperature range and to adjust pitch and polarization. The temperature dependence of the important physical parameters were measured and compared with theory. Besides the electrooptical phenomena the electromechanical response of the substances was intensively studied. By means of laser light induced thermal gradient the order electricity of nematic liquid crystals was also investigated.

Dielectric spectroscopy studies of different liquid crystal structures including ferroelectric phases and their phase transitions have been continued. The temperature dependence of the spontaneous polarization and of the tilt angle was interpreted in terms of a new molecular model.

New research projects have been started:

1. Introduction of the stochastic diagnostic technique and the effects of white noise.

2. Studies of pattern forming instabilities (permanent and transient): viscous fingering, solidifying fronts and electrohydrodynamic instabilities.

We investigated the nonlinear optical properties of absorbing nematic liquid crystals and demonstrated resonatorless optical bistability with the help of dichroic dyes. It was discovered that certain dyes considerably enhance the orienting action of light radiation.

Materials Research

Materials research has been focused mainly on rapidly quenched (amorphous or micro crystalline) alloys and, to a small extent, on crystalline metals.

Research on rapidly quenched metals

The influence of hydrogen absorption on the structure and properties of amorphous alloys was studied in collaboration with domestic (universities of Budapest, Debrecen, Szeged) and foreign (Williamsburg, USA; Tallin, USSR; Stuttgart, FRG; Wien, Austria) partners in the framework of a research programme of OTKA of the Hungarian Academy of Sciences. Methods have been developed for preparing metal-metal glasses by the melt-spinning method in a vacuum and with inert gases, for hydrogen absorption at pressures up to 30 bar, for determining to hydrogen content by thermo-electric power measurements, etc. A measuring head and a second transmitting set have been developed for double NMR resonance measurements.

The main results are connected with the electron structure, anomalous 1/f noise of disordered structures, hydrogen induced phase-separation, the diffusion of hydrogen, high resolution double NMR and the detection of "photo" and "thermo" protons.

In the research of soft magnetic amorphous alloys relationships have been established between the processing parameters, composition and the magnetic properties. A new method has been developed for detecting magnetic domain structure by scanning electron microscope. Prototypes of different sensors and inductive elements (coils, transformers) have been produced from soft magnetic amorphous alloys.

The procedure and pilot plan equipment have been elaborated for preparing silver based dental alloys of microcrystalline structure. The manufacture of these alloys is in progress in VASKUT, Budapest, under the trade name HOMODENT .

Research of crystalline metals

In collaboration with the University of Louvain (Belgium) a new method was developed to study the electron structure of metals based on the beta-decay of implanted B^{12} isotopes. We has thus been able to determine the hyperfine field of boron occupying interstitial sites, the Koringa constant and the Stoner enhancement factor in noble metals.

Neutron Scattering Research

Even though the reactor was being reconstructed over the past few years neutron scattering studies were continued in cooperation with neutron research centres abroad: Dubna, Saclay, Grenoble, Seibersdorf, etc. The amorphous Ni-Nb system was studied by high momentum transfer, and the experimental description of short range order (also affected by the onset of crystallization) was given.

Structures and dynamics of organic salts in aqueous solutions were investigated by small angle and inelastic neutron scattering. The short range order in amorphous semiconductors (Si, Ge) was determined in order to refine the theoretical structure models. Order-disorder transformation in liquid crystals were also studied by neutron scattering experiments and a model was established for the phase transformation in nematic-smectic type materials. Materials science investigations were also carried out by neutron radiography and diffraction methods. Dynamic neutron and gamma radiography were utilized in the case of several industrial constructions.

Amorphous Semiconductors

In the period under consideration two important problems of amorphous materials were studied, namely the middle-range order and the behaviour of the metastable states.

The universal line-shape of the boson peak in the low frequency region of the Raman spectra of different amorphous materials can be attributed to the lognormal distribution of cluster sizes; lognormal distribution appears to explain the intermediate range order of amorphous structures. Current fluctuation at frequencies below 10 Hz in intrinsic a-Si:H samples shows dominantly 1/f character. The fluctuation process, in general, presents non-Gaussian behaviour. A strong analogy was found between the inhomogeneous broadening of spectral lines and the 1/f fluctuation in amorphous materials.

The nature of metastable states in a-Si:H was studied by DC conductivity and DLTS (Deep Level Transient Spectroscopy) measurements. The generally observed kink in the Arrhenius plot of DC conductivity can be explained by the presence of metastable states and can be influenced by heat treatment of the film.

Field induced doping effect was introduced in undoped and variously doped a-Si:H samples. DLTS and TSC (Thermally Stimulated Capacitance) data show the reversibility of this process and the changes in the density of states in the forbidden gap of the semiconductors. They offer a further explanation for the doping process of amorphous silicon and for the behaviour of the metastable states in amorphous structures. Applying the results of our research, a fast photo detector was developed, with a response time better than 50 ps.

Laser Physics

The energy spectra of photo electrons induced by high intensity (GW/cm^2), ultrashort (psec) laser pulses from gold were measured. In contrast with expectation, the appearance of unexpectedly high (up to 600 eV) energy electrons

was demonstrated. In subsequent measurements we succeeded in observing the so called multiphoton "Above Threshold Photoeffect" (ATP) peaks in the photoelectron energy spectra. This type of energy spectrum contains 10 ATP peaks, separated by the photon energy $h\nu$ of the laser. However, this discrete peak structure appeared even at $\sim$100 MW/cm^2 intensities, $\sim$4 orders of magnitude lower than predicted by the QED. (For details, see also Selected Topics.)

Laser oscillation was investigated in a short 3 cm active length infrared hollow cathode He/Cu^+ laser. This laser operated at the very low threshold current of 0.3 A. The optimum gas pressure increased with increasing discharge current in the He-Cu^+, He-Kr^+ and He-Ar^+ lasers, whence we concluded that this relation is a general law for hollow cathode lasers. At the 694.4 nm line of the Kr ion increased Doppler broadening was found; this is explainable by the excess kinetic energy taken up by the Kr ion from collisions with He 2^2S metastable atoms. A Monte-Carlo model was developed for noble gas mixture hollow cathode discharges. The predicted current density - voltage characteristics were in agreement with experimental results.

Light reflection measurements on silver covered holographic gratings resulted in a gap structure in the surface plasmon dispersion plot, which is similar to that observed earlier in our laboratory in MOM structures (i.e. momentum gaps at the crossing points, of SPO (Surface Plasma Oscillation) dispersion functions). The initial experiments for determining the surface plasmon lifetime with a scanning tunnel microscope at a wavelength of $\lambda = 633$ nm yielded $\tau \sim 50$ fs, which is much smaller than the value calculated for an ideally smooth surface.

Laser Application

Research and development covered the following main areas:

- development of solid state (crystalline and glass) lasers and their applications in industry and medicine;
- development of optical measuring instruments like airborne particle counters and clean room monitors; interferometric measuring instruments and motion analyses; optical anemometers;
- development and production of optical coatings.

Participating in the E-226 EUREKA project (High Power Solid State Lasers) we developed high power Nd:GGG-lasers of high efficiency (rod and slab). In the frame work of the Joint Group for Laser Research we realized efficient laser action in Er:YAG and Er-glass (Q-switched) materials.

The airborne particle counter has a very high upper limit for measuring the concentration of the given particles. It can be used in toxicology, pharmacology, environmental monitoring, etc. The lowest size of measured particles is 0.3 μm. The laser interferometer is a modular system for measuring the geometrical parameters with high precision.

The motion analyzer is a laser interferometer with sampling storage for all parameters of the movements with interferometrical precision. It is especially useful for studying dynamic phenomena such as transients or stick-slip.

The optical anemometer is a non-contact instrument for measuring the velocity of the target by statistically analyzing the scattered light.

Computer software developed by researchers of the Optical Thin Film Laboratory reduced significantly the time necessary for designing new optical coatings. The most important developments include broad band multilayer dielectric mirrors for Ar^+, Kr^+, and Ti^{3+}:Al_2O_3 lasers, antireflection coatings of Nd,Cr:GGG laser rods and LBO crystals, a number of different optical coatings for the optical head of a rewriteable magnetooptic disk driver system, optically transparent and electrically conducting ITO layers, etc. In the field of nonlinear optics our researchers investigated the optical bistability of nonlinear interference filters containings CdS_xSe_{1-x} semiconductor mixtures.

Multifractal Description of Chaos

A. Csordás

The behaviour of chaotic dynamic systems is one of the main subjects in statistical physics. Chaotic motion can be regarded as the solution of a deterministic non-linear equation of motion of stochastic nature. This phenomenon is quite common not only in physics but in other fields of sciences. Generally the phase space points, visited by the trajectory after a transient, are distributed on a fractal, and the stationary distribution on this fractal has very different local singularities. To describe them the concept of generalized dimensions was introduced. However, the details of the dynamics cannot fully be extracted from the generalized dimension thus another spectrum, the generalized (Renyi) entropies, is necessary for investigating the time evolution of chaotic systems. Both spectra can be derived from the thermodynamical formalism worked out for chaotic models.

The simplest model systems on which the basic ideas can be studied are the one dimensional maps. We have shown that a phase transition occurs in the entropy spectrum of intermittent systems. We have identified two phases. The first is common for chaotic systems, the second can be interpreted similarly to the condensed phase in equilibrium statistical physics. We have found, however, a different type of phase transition in another borderline case of chaos, when an unstable periodic orbit exists with infinite Lyapunov exponent. In this case the critical parameter q_c of the thermodynamic formalism at which the phase transition occurs is between 0 and 1. Below q_c all the entropies are infinite. We have shown that this new phase transition is present in a map characterizing a chaotic cosmological model (the "Mixmaster" universe). These investigations made possible to classify the different phases of chaos, and to establish connections to phenomena of condensed matter physics.

Dielectric Relaxation of Spin Density Waves

G. Mihály

The periodic spatial modulation of electron spins is a fundamental broken symmetry ground state of the quasi-one-dimensional electron system. The wavelength of the spin modulation is determined solely by the electron system, the period is independent of the underlying lattice. In the past ten years spin-density-waves (SDW) were experimentally observed in various linear-chain organic materials. The most direct evidence of the new magnetic structure was provided by NMR experiments.

While the magnetic behaviour resembles that of a conventional antiferromagnet (with unusually low local momentum), there is a wide variety of electronic excitations. Due to the misfit in the periodicities the spin-density-wave is only slightly pinned to the lattice and at low temperatures the displacement of the density wave dominates the charge transport. We have performed nonlinear transport and low-frequency dielectric measurements to characterize the collective mode dynamics.

As an example, Figure 1 shows the dielectric response in the SDW state of $(TMTSF)_2PF_6$ at T = 2K. It demonstrates the collective mode contribution to the dielectric properties (ε_{sp} is the single particle dielectric constant) and also reveals huge static polarizability. The variation of ε spreads over several frequency decades. This is suggestive of glassy behaviour; the weak relaxation of low-lying excitations indicates metastable pinned SDW configurations.

The field and frequency dependent response of the SDW shows similarities with the phenomena observed in charge-density wave systems (CDW). In contrast to CDW, however, spin density waves are not coupled to phonons. This point has important consequences in SDW dynamics, as indicated by preliminary experiments performed below 1K.

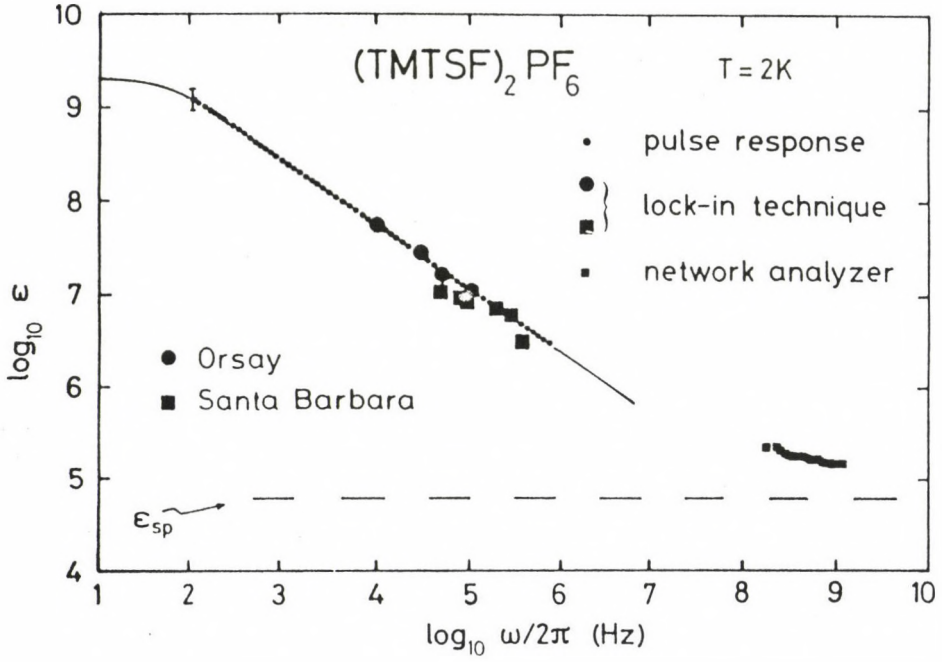

Fig. 1

Ordering of Oxygen into Chains in $YBa_2Cu_3O_{6+x}$

A. Jánossy

Recently we have described [see Ref. 1] a local method, Gd^{3+} EPR, for determining oxygen ordering in Gd doped $YBa_2Cu_3O_{6+x}$ Based on detailed EPR analysis, we presented the assignment of EPR lines to the local oxygen chain configurations and determined their concentration dependence.

A series of 0.1% Gd doped $YBa_2Cu_3O_{6+x}$ powder samples was prepared, embedded in epoxy and oriented in a magnetic field. EPR spectra were taken with their static magnetic field along c.

The EPR spectra correspond to the fine structure of the $S = 7/2$ Gd^{3+} ion. The -7/2 → -5/2 transition line is used for further analysis. The narrow line at $x = 0$ splits into 5 new lines with increasing x. Each line is observed in a limited range of x at a nearly constant position.

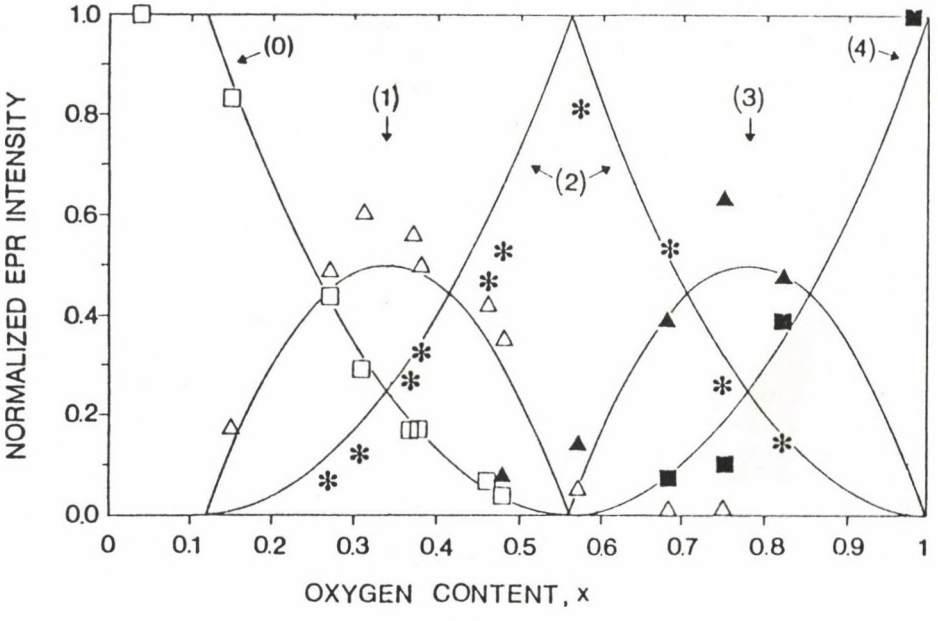

Fig. 1

Concentration dependence of the relative amounts of local chain configurations. Open square, open triangle, asterisk, full triangle and full square represent the 0, 1, 2, 3 and 4-fold occupied configurations, respectively. Full lines are calculated curves.

Assuming that oxygen is ordered in chains, each Gd has 4 first neighbour positions, which may be occupied by 0, 1, 2, 3 or 4 oxygen chains. The assignment was based on the relative intensities of EPR lines determined by a computer fit.

Figure 1 shows the concentration dependence of the normalized line intensities. With increasing x, the intensity maxima of the 0 1, 2, 3 and 4-fold occupied configurations appear in order. This assignment is supported by the position of the lines: at higher occupancy the corresponding line appears at higher field, following the increase of the relevant crystal field parameter. We suppose that configurations containing disordered oxygen result in an EPR line which is too broad to be detected.

The full lines of Fig. 1 represent the concentration dependence of the amounts of Gd found in each of the 5 configurations with the above assumptions and a chain distribution suggested by de Fontaine et al. [see Ref. 2]. We find good agreement with the experimental data [see Ref 1]. The following regions are distinguished:

$x < 0.12$:	oxygen is disordered all chains are vacant;
$0.12 < x < 0.56$:	0,1 and 2-fold occupied configurations;
$0.56 < x < 1.00$:	2,3 and 4-fold occupied configurations.

At $x < 0.56$ the amount of disordered oxygen is 0.06 and only the 2-fold occupied configurations is expected to occur, corresponding to alternating vacant and occupied oxygen chains in ab planes.

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Application of Time Interval Statistics for Determining Velocity in Fluid Flow and on Solid Surfaces

P. Jani, A. Czitrovszky

A practical realization of a data collecting scheme for velocity measurement in fluid flows and on solid surfaces is described.

Such a measurement is based on the statistical evaluation of time intervals between photon density events. If the number of registered photo-electric impulses of a photomultiplier tube (PMT) exceeds a preselected value during a preselected integration time a density event impulse (DEI) is triggered. These density event impulses are further analyzed statistically in accordance with the block diagram shown in Fig.1. Formed PMT pulses are derandomized to coincide with the 20 MHz system clock and are transmitted to the input of the scalers gated one after another in a cyclic order. Whenever an overflow occurs in any of the scalers a DEI is emitted that stops a memory cycle and starts a new one. The memory content of the channel

corresponding to the time interval between the last DEI and the last but one is increased by 1. The memory content is autonomously displayed on a conventional oscilloscope, whereby the time delay of two adjacent maxima can be deduced from the time base of the oscilloscope. This time delay corresponds to the time of flight of the scattering particles between two adjacent maxima of the illumination pattern, separated by a known distance.

With this method a direct and simple assessment of velocity can be achieved. Successful experiments were carried out for the non-contact determination of the velocity of rotating machine tool parts and other moving surfaces. The method also shows great promise in fluid and gas dynamics.

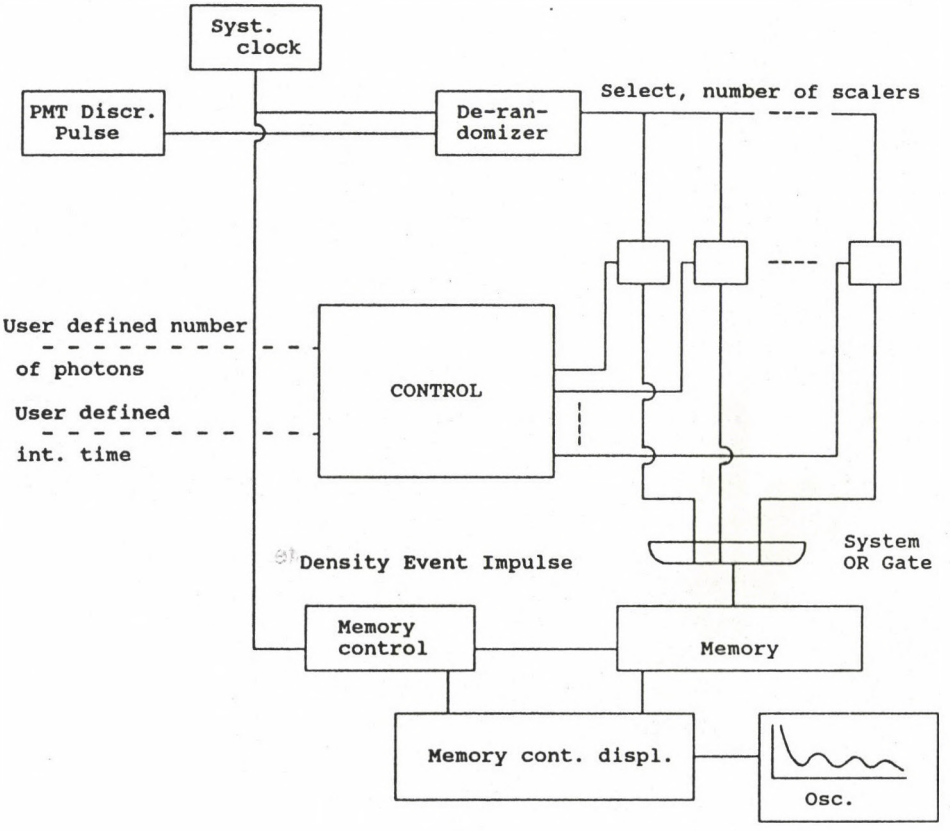

Fig. 1

Clustering in TM-Based Metallic Glasses

A. Lovas, E. Kisdi-Koszó

It was recently recognized that the existence of clusters has an important role in the structural description of the glassy alloys formed during rapid solidification. It is highly probable that the size-distribution and local composition of the clusters are structural manifestations of the associations already present in the glassforming melts.

The aim of our activity is to supply experimental evidence for the existence of the clusters in transition metal (TM) based-metalloid glasses: in particular, to show how the systematic change in the composition can influence the cluster-formation tendency, and to give a qualitative interpretation of the alloying effect within the framework of clusterforming phenomena. The hypo-eutectic $Fe_{85}B_{15}$ basic alloy is especially suitable for this purpose. Alloying was carried out by replacing the Fe host metal by a small amount (max. 5at%) of transition or noble metals.

As the basic alloy is a good glass-former, it can also be characterized by the strong compound-forming ability between the components. This ability manifests itself in the formation of the maximum possible number of Fe-B contacts having high bonding energy. Consequently, there is a compound-like short range order in it. A further consequence is that nearest neighbor concentration distribution around the boron atoms differs from the mean composition of the glass. The remaining fraction of the Fe-atoms are crowded in iron-rich clusters during the solidification process. In view of this the binary glass consists of compound-like associations and iron-rich clusters as well, so a concentration fluctuation is developed in a 2-5 nm scale, which is usually called the medium range order.

The host-metal replacement can modify this clustering of the basic alloy through its microdistribution between the clusters. Microdistribution is governed basically by the chemical affinity between the alloying metal and boron. Those metals with higher affinity for boron than for the Fe host will partly displace the iron atoms from the environment of boron. Others, like Pt or Au, which form less stable borides than the host metal, will be enriched outside the compound-like associations: either in the Fe-clusters, or in independent clusters.

Regarding the amorphous-crystalline transformations, we found that even a few atomic percent host metal replacement can significantly change both the temperature and the mechanism of crystallization. This indicates that the second metal influences the bonding strength through a local mechanism.

As far as the magnetic properties are concerned, the iron rich cluster similarly to the amorphous iron is assumed to be nearly nonmagnetic, the ferromagnetic behaviour being government by the compound-like associations.

Corresponding to the microdistribution of the alloying metals in the diluted concentration range, metals forming more stable borides than iron drastically reduce the magnetic moments and the Curie temperature whereas additives such as Pt that do not form stable borides increase the value of these two parameters.

Structure of Amorphous Matter: an Apotheosis of Lognormal Statistics

I. Pócsik

The general applicability of lognormal statistic was recently discovered as a means of interpreting the structure an properties of non-crystalline materials. This structure can be described by a cluster model, the clusters of which have a broad lognormal size-distribution.

The most characteristics feature of lognormal distributions is that the results of the elementary probability processes should be multiplied together to get the final result, in contrast to addition in the Gaussian and most of the other distributions. The breaking process is a good example of how this multiplicating mechanism works. One piece of stone will break or not, and will break again. The stone's size will be roughly a half, a quarter, an eighth of the original size, and so on. The final size of the stones will be determined by the product of the suffered events, the breaks.

Another important feature of lognormal distribution is its dimension-independence, which is simply a consequence of the logarithm in the definition.

Since Kolmogorov's important discovery, we know that the size-distribution of the swirls in a fully developed turbulent dissipative hydrodynamic system follows lognormal distribution; this property has the consequence that a number of elements of different size but of this distribution, can be closely-packed. It was proved that metal clusters, condensed in a cooled gas, follow this size-distribution. The characteristic asymmetric spectral lines in the different spectroscopic methods, such as optical, Raman and NMR spectra, were also demonstrated to have such a line-shape. A common feature of these spectral lines is their spectral inhomogeneity.

The relaxation phenomena also show a temperature dependence that can be described only by this distribution. A common feature of amorphous matter is the non-Debye relaxation. This behaviour is strongly related to the inhomogeneity of the spectral lines. In the crystalline case the relaxation time versus inverse temperature gives a straight line, where the activation energy of the motion can be extracted from. In amorphous matter we usually get bending curves, which can be explained by activation energy distribution. The loss of the single value of the

activation energy creates a situation similar to inhomogeneity; we do not have a single thermodynamic system, we have different sub-systems having different temperatures.

This cluster description already generates fractal features. The self-similarity is there in the broad size-distribution of clusters. The multiplication plays a central role in both the fractal system and in lognormal statistics. The continuous distribution can be described as a multi-fractal set.

On the basis of the above, it can be concluded that the structure of non-crystalline condensed matter can be described by a cluster model, where the clusters follow lognormal size-distribution. The fractal description combined with lognormal statistics can be for amorphous materials an idea as general as is periodicity in the case of crystals.

Laser Induced Photoelectrons from Metals with Unexpectedly High Energies

Gy. Farkas, Cs. Tóth

In the course of the last two years we investigated the new forms of laser induced photon-electron processes that occur in the case of the photoelectron emission initiated by extreme strong laser pulses from the surface of metals. We have revealed that some of the pohotoelectrons are emitted at unexpectedly high ($\sim$ 600 eV) energies, in contrast with the expectations following from the Einstein's equation according to which these energies may be at most of the value $h\nu$ which, for our laser frequency is 1 eV. In the following we present in a shortened form the relevant theoretical background together with our previous results in this topic [Ref. 1 and references therein], a description of the recent experiments and the results that have recently been obtained [see Refs. 2-4].

Theoretical backround

The general and exact description of the photon-electron interaction in question is given by quantum-electrodynamics (QED). Accordingly, the interaction process may be studied in a transparent way in terms of the strength of the applied perturbation.

Withen the validity range of the perturbation approach (relatively low laser intensity) the photocurrent is given by the n_o-th order perturbation approach, where $n_o \equiv A/h\nu$ is the photon number necessary to overcome the potential depht "A" (work function) of the metal. The emitted electrons may be considered as free the kinetic

energy E_k of which is furnished by the generalized Einstein's equation as $n_o h\nu = A + E_k$. This phenomenon is called "multiphoton photoeffect", first demonstrated in our Laboratory many years ago [in Ref.1].

Beyond the limit of perturbation calculation (higher laser intensities) the emitted electron's final state will form now one of the so called "Volkov-states", which are induced by the no longer negligible laser field outside the metal. These states are discrete and are separated by the photon energy $h\nu$. The order of the interaction in the s-th state is therefore $n = n_o + s$, with $s = 0, 1, 2 \ldots$ The light intensity dependence of these processes deviates more and more from the n-th order power law, their energy relation being given by another form of Einstein's equation in which $n = n_o + s$ appears (with s being of the order of 10) instead of the former threshold value n_o. The process is called: "Above Threshold Photoeffect" (ATP). Byfurther increasing the laser intensity the order n of interaction tends to infinity, and the process will have according to QED the form of classical cold emission, i.e. "optical tunnel emission" with its well known current formula. The first demonstration of this phenomenon was also performed by us some years ago [in Ref.1]. The energy formula here is expressed by an even more general form of Einstein's equation, with the modified work function $\acute{A} = A + \varepsilon$, where $\varepsilon = eE/4m\omega^2$ is the known classical oscillation energy of the electron in the classical e.m. (laser) field of electric amplitude E.

Our experimental work during the past two years was concentrated on studying the energy spectrum of the emitted photoelectrons conditions in which the the above mentioned forms of Einstein s equation might be realized.

Experiments

In our experiments strong ultrashort (psec) light pulses of neodymium-laser systems ($h\nu = 1.17$ eV) were directed at grazing incidence and p-polarization onto the surface of a thick gold ($A = 4.67$ eV) plate kept at ground potential. Then the order n_o of the first nonvanishing perturbative term (i.e. the threshold term) is $n_o = [A/h\nu + 1]_{int} = 4$, as was verified in our many previous works. Therefore, the electrons's kinetic energy to be extracted from the simplest multiphoton Einstein-equation would be $E_k = n_0 h\nu - A = 0.1$ eV.

The space charge phenomenon caused by the short, high current pulse of the emitted electrons (which may falsify totally the original real energy distribution) was fully eliminated by placing a mesh in front of the grounded gold target and keeping it at sufficiently high positive extracting potential. Behind the mesh a special retarding field energy analyzer system was used whose entrance diaphragm was kept at the same potential as the gold target to reobtain the original space-charge-free electron energy spectrum. The overall interaction system was situated in a vacuum vessel pumped down to 5×10^{-8} mbar by a turbomolecular pump.

The measurement consisted of the determination the integral distributions of the photoelectrons: we measured the number of electrons emitted as a function of the retarding voltage applied to the analyzing system at constant laser intensity. First we eliminated the space charge: by increasing the extracting electrode potential the photoelectron yield at first increased but above + 15 kV did not change any more, which fact presented the complete space charge elimination. Under the conditions realized in this way, we could already measure real original energy distributions.

Results

The electron energy spectra were determined in the 13-25 GW/cm^2 laser intensity interval. Owing to the strong laser intensity fluctuations, we could determine only the envelopes of the energy distributions; it was not possible to resolve the above mentioned shν ATP peaks. From the integral energy distributions we derived the differential ones numerically, the maxima of the latter varied from 100 eV up to 600 eV on increasing the laser intensity from 13 GW/cm^{2}up to 25 GW/cm^2.

We also measured the "photocurrent laser intensity" relations at various electron energies; the dependences proved to follow power laws with very high exponents. This result presented an additional check, demonstrating the higher order character of the investigated processes.

The $\sim$ 600 eV electron energies obtained are quite unexpected and surprising as we shall see in the following. Based on the introduction the following energy values follow from the different forms of Einstein's equation: from its simplest multiphoton form $E_k < h\nu$ (at $<10^8$ W/cm^2 intensity), from its ATP form $E_k \sim sh\nu$, with s = 0, 1, 2 ..., $\sim$ 10 (at $< 10^{14}$W/cm^2 intensity), and from its tunnel form $E^k \sim sh\nu$, with $s \to \infty$ (at $> 10^{14}$ W/cm^2 intensity). Now, in contrast to the case of atoms, where the respective s values more or less corresponded experimentally to the above-mentioned intensity ranges, our experiments demonstrated that this correspondence is no longer valid for metals. It turned out that if, somehow, the s-values could be attributed to the observed high energies, this effective s value would have to be as large as 600 even at very low laser intensities (10^{10} W/cm^2), i.e. at intensities 4 orders of magnitude lower than predicted by QED. Although at this s $\sim$ 600 value we might imagine some tunneling-type process, the inducing 10^{10} W/cm^2 intensity purely corresponds to the multiphoton limit, as we demonstrated earlier [see Ref. 1]. Therefore this new observation cannot be explained by the simple application of the above mentioned theory. Similar conclusions were drawn by others in France, USA and Germany, who meanwhile repeated our experiments.

In summary we have measured the energy spectrum of the photoelectrons induced from gold by high intensity ultrashort laser pulses: in contrast with the

expectations we demonstrated the appearance of unexpectedly high (up to 600 eV) energy electrons even at surprisingly low laser intensities. (As for our other work in progress see the footnote*.)

The theoretical interpretation of this new phenomenon is not yet solved, therefore the results will certainly strongly stimulate the development and generalization of the theory of photon-electron interaction.

In addition to the fundamental theoretical interest, the strong, high energy electron emission obtained has further practical importance in the realization of new type high current density pulsed laser cathodes [see Refs.5, 6] for accelerators and for free-electrons lasers.

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*It should be noted here that in our subsequent recent measurements [see Ref. 4] we succeeded in demonstrating ATP peaks in a much lower intensity range ($\sim$ 100 MW/cm^2). Here the energy resolution with a precision $h\nu$ was already possible, we have obtained ATP peaks up to $s < 12$ values, i.e. it turned out that the electron energy spectrum – at least in the low laser intensity range – really had a discrete peak structure. However, this peak structure appeared again at $\sim$ 4 orders of magnitude lower laser intensities than predicted by the QED.

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KFKI RESEARCH INSTITUTE FOR MICROELECTRONICS (MKI)

1. Research on Magnetism

Light-induced magnetic, electrical and optical effects are related in charge uncompensated Ca:YIG epitaxial garnets. The mechanism behind these effects was studied [59]. The influence of the sample size on the magnetic properties was investigated in epitaxial garnets, and the thickness dependence of the magnetic parameters and the effect of mechanical stress on them were also determined [98,99].

Investigations proved that domain wall coercivity is the best measure of the correlation between the magnetization process and the structure of defects. The temperature dependence and the effect of internal magnetic field gradient on the domain wall coercivity were measured in epitaxial garnets. The magnetization process was followed by measuring the stability of the amorphous magnetic state against asymmetric magnetization reversal, by modelling the magnetic hysteresis curves and comparing the results with measured curves in crystalline and amorphous ferromagnetic materials [8].

2. Research on Implantation Defect Dynamics and Thin Films

2.1. An approach to shallow junction preparation

Studies of defects influencing the production of shallow pn-junctions were performed in cooperation with the Frauenhofer Arbeitsgruppe für Integrierte Schaltungen (FAIS, Erlangen) within the EUREKA project as part of the program

"Basic and Long Term Research" of JESSI (Joint European Semiconductor Silicon). The present work belongs to studies of how to overcome inherent problems of ion implantation during the production of 70 nm deep pn-junctions for 0.25 μm design rules (64 Mbit DRAM or equivalent).

Based on early experience (a joint CalTech-KFKI result: J.W. Mayer, L. Csepregi, J. Gyulai, T. Nagy, G.Mezey, P. Revesz, E. Kotai: Thin Solid Films 32, 303 (1976)), three ideas have separately been explored to date.

a) The formation of End-of-Range (EOR) disorder was found [51] to correlate with as-grown impurities of silicon wafers, such as oxygen and carbon. These are mainly responsible for the formation of the EOR disorder. Thus, the use of float zone or denuded silicon is preferable.

b) Vacancy type defects accumulate in the near-surface region, whereas the interstitial type is deeper. Using multi-energy preamorphization, better recombination kinetics was achieved thus by reducing transient diffusion of the boron. Ti-silicided diodes proved the effect [9].

c) Following our earlier results on annealing under UV irradiation as well as the results of others (N.P. Morozov, D.I. Tetelbaum: Phys. Stat. Sol.(a) 51,629,(1979) and experiments by J.N. Erokhin et al.: Pisma v Zhetf, 836, 14, (1988) using 200 keV As implant), the influence of (2.5 eV) photon irradiation during 20 keV B and As ion implantation resulted in 20% shallower junctions. (Experiments were performed jointly with the Department of Electronic Devices, Technical University of Budapest, and were financed by the State Office for Technical Development). Experiments to combine the three ideas in order to produce good and shallow junctions are underway.

2.2. Optical studies of implanted layers

Comparative studies on the modifying effect of ion implantation was carried out by ellipsometry, TEM and Rutherford Backscattering Spectroscopy and channeling. Combined and cross-checked data from these methods enabled us in many cases to make use of the non-destructive nature of ellipsometry to study implantation damage and other structures (e.g. Silicon Implanted with Nitrogen, SIMNI) in or on semiconductors [19]. An automatic ellipsometer and our program package will be used to study real-time surface reactions.

2.3. Experimental studies of basic implantation phenomena

2.3.1. Studies on the amorphous phase

Thin films and surfaces with amorphous properties were prepared by combining thin film technology with ion implantation, low-energy noble gas ion

bombardment, solid phase epitaxy or solid phase reaction. The structure, composition and electron density of states of the samples were investigated by means of UPS,XPS,XDR,TEM,RBS.

Anomalously amorphous Ge was induced by heavy ion implantation. It was shown that the amorphous-crystalline transition of ion implanted layers in Ge and in Si does not fully fit into the generally accepted solid phase epitaxy picture since the surface cannot regrow fully. Slightly (1-5^{o}) misoriented domains were found even, when the implantation was done under UHV conditions [64]. This partially regrown surface layer may induce near-surface defects [107].

2.3.2. Comparative studies of atomic and molecular ion implantation

Equi-density cascades were produced by atomic and diatomic molecular species in silicon at different implantation temperatures. The amorphization efficiency was clearly subject to competing phenomena of amorphization and beam-assisted regrowth. The molecular effect is able to increase amorphization by a factor of more than ten. At a cross-over temperature, the molecular effect disappears [106].

2.3.3. Morphological changes in high-dose implantation

Surface deformation (wave-like structure) is caused by high-dose implantation similar to fatigue striations in metals. The observed general phenomenon was successfully described theoretically and the control parameter was found [20,29].

2.3.4. Increase of film adhesion by implantation

The adhesion of Ti_2O_5 optical films was improved by Ar implantation, the optical constants were unchanged at low doses [101].

2.3.5. Implantation into magnetic materials

The influence of ion implantation on the magnetic properties of amorphous iron-based alloys was investigated. From the temperature dependence of magnetization, the surface magnetization properties, and from ferromagnetic resonance measurements and scanning tunneling microscopy it was shown that implantation of N^+ produces partial crystallization of the surface layer. As a consequence, mechanical stress also occurs and alters the magnetic properties [74].

2.4. Thin film studies

The conditions for the epitaxial growth of Gd-silicide on Si(111) and Si(100) were determined.

The oxidation of the strongly reactive Gd can be decreased by means of Si atoms diffusing through grain boundaries of Gd films [54].

The density of states of $Ni_{50}Zr_{50}P$ is changed by H via H-Zr reaction and structural modification [62].

Gold migration on Si-SiO_2 substrate depends on the thickness of the Au film because of the variation in the ratio of grain size to thickness [65].

3. Studies on Crystal Growth

3.1. GGG crystals for laser applications

Double or multiple doped $Gd_3Ga_5O_{12}$ crystals (GGG:Nd,Cr or GGG:Nd,Cr,Ce) have several advantages in pulse operated lasers. The crystals can be grown to large diameters and length and are free from optically inhomogeneous regions which would limit the efficiency of growth and the preparation of large laser slabs. The conditions of energy transfer from Cr^{3+} to Nd^{3+} are much more favourable in these crystals in which a twofold increase in laser efficiency can be achieved. Our thermal conditions are optimized for growing crystals of 22 mm diameter by 100 mm length with a flat interface. A series of crystals were grown under strictly similar conditions to determine the optimum composition for laser operation.

3.2. Studies of epitaxial growth on GGG crystals

Thick, nominally pure YIG and Bi-substituted YIG single crystal layers have been prepared by the liquid phase epitaxial (LPE) method from a high temperature solution. We found that a pure YIG layer on GGG substrates can be grown by the usual isothermic LPE method up to about 70-80 μm in thickness without surface defects. If one modifies the conventional LPE method and uses Y-substituted GGG as a substrate, the layer thickness can be increased up to 400-500 μm without spontaneous nucleation and cracks [90].

3.3. Crystalline high-Tc materials

High-Tc superconducting single crystals with $YBa_2Cu_3O_7$ (YBCO) and $Bi_2CaSr_2Cu_2O_8$ (BCSCO) nominal compositions were grown by (i) the cooling flux

method and (ii) the LPE method. Typical dimensions and T_c of the bulk YBCO single crystals were 3x3x0.1-0.2 mm^3 and 93 K, respectively, while those of bulk BCSCO single crystals were 5x5x0.2 mm^3 and 85 K, respectively, after O_2 heat treatment [41].

3.4. Research on growth technique

An adaptive controller based on real-time modelling of the system was developed for the Czochralski growth of $LiTaO_3$, $Bi_4Ge_3O_{12}$ and $Gd_3Ga_5O_{12}$ crystals. The dynamic behaviour of the growth process was characterized by a discrete-time linear ARMA model which relates the heating power to the crucible weight error. Besides the mass variation due to the solidification, the weight measured during growth consists of force components due to capillarity. In order to estimate the real radius (and the solidification rate) variation, we have developed a digital filter that produces the radius error as a filtered version of the measured weight error. By using the adaptive controller and the radius estimator filter, we were able to detect, experimentally, some important and theoretically predicted features of behaviour (instability, oscillating behaviour, effect of capillarity on weight dynamics, etc.) of the Czochralski system [38].

3.5. Theoretical studies

The effect of the electric field on the order-disorder transitions in lattice-gas models exhibiting anisotropic particle distribution was studied. In these systems the particles can form parallel chains along one of the crystallographic directions. The equivalence between the different directions is broken when the particle jump is biased by an electric field. Monte Carlo simulations have demonstrated that the chains prefer the direction parallel to the applied field. Some theoretical approaches have confirmed that the chain orientation may be modified by the application of an electric field. The superionic phase of AgI is considered as a candidate for the experimental realization of the reorientation process. Furthermore, this non-equilibrium transition phenomenon may potentially be of relevance to the properties of certain superconducting oxides [81,82].

4. Scanning Tunneling Microscopy

Theoretical investigations for various model calculations as well as preparatory studies for possible experimental research in connection with Scanning Tunneling Microscopy (STM) have been done [3].

5. Studies in Optics

Wide angle interference was experimentally studied with the purpose of using the radiation of a single atom or molecule as a source. As a first step, Selényi's first experiment (Annalen d.Phys. 35. 444. 1911) was repeated with an up-to-date experimental technique. Using a ground glass surface as our object, interference was observed between waves scattered at 136^{0}. Though Selényi was very careful to avoid any parasitic interference, we detected a possible source of error, which gives a similar interference pattern to that of the wide angle but at a small angle. Evaluation of the pattern proved that interference was really produced by waves emitted at the wide angle. Data obtained by two independent measurements agree within an accuracy of 2% [91].

6. Work on Environmental Protection

Scanning Electron Microscopy (SEM) combined with Electron Probe X-ray Microanalysis (EPXMA) was used to perform morphological and chemical characterization of microscopic particles (aerosol, flue dust, coal fly-ash) to identify the emission sources polluting the atmosphere and to qualify emission. Micro X-ray Fluorescence in SEM provides additional results on trace elements in pollutant dust with a lateral resolution of 0.2 mm and a detection limit of 10 ppm [79].

7. Development of Technological Equipment

With regard to instruments for technology and testing, our activities were extended toward the application of laser beams in microelectronic technology. In the period covered by this Yearbook we have developed equipments for a number of applications, viz. Laser Activated Chemical Vapour Deposition (LACVD), Laser Pantograph (LPF), Laser Pattern Generator (LPG), IR Spectro-fluorimeter, in-situ Ellipsometer and some additional units (e.g. energy control unit for excimer laser, autofocus unit, etc.). In order to fully automate equipment the IBM-PC compatible module system (PICA) has been developed for data acquisition and process control. User friendly, menu driven software supports the users in the operation of the equipment.

In the field of ion beam techniques a long-life, hollow cathode ion source was developed for KFKI's Heavy Ion Cascade.

Switching mode, high voltage power supplies with IR remote control have been produced for various purposes.

In the framework of microcontroller-governed measurement-specific instruments, the following equipments have been developed:

- TELECONT automatic critical dimension (CD) measurement system (This is capable of defining CD's as small as 0.7 micrometers with reasonable accuracy),
- automatic focusing equipment,
- real-time image store (frame grabber),
- programmable 1-,2- or 3-axis step motor controller,
- microdefect analyser unit,
- active memory card.

A laser based pattern generator and stepper was constructed, which involves dynamic focusing and chopping of the CW beam of a He-Cd laser to an accuracy of about two microns for reticle generation. The whole programme including precision mechanics, hardware and software is available either in-house or through local subcontractors. When using the machine as a stepper it can be offered complete with mask processing and testing in a package.

Another development relates to the elaboration of two laser based mask repair stations: LRS 901, and LRS 902. The LRS 901 was designed first of all to repair opaque defects of hard chromium reticles and masters used mainly in the semiconductor industry, but the machine is suitable for repairing or trimming other thin metal films by modifying the processing parameters. Opaque defects are removed by means of a frequency doubled Q-switched Nd:GGG pulse laser. The laser beam is focused onto the surface to be removed: it causes the ablation of the excess metal layer. The shaped laser spot size (minimum 2×2 microns) and power are controlled to ensure the user's demands relating to the quality of removal. The system is equipped with computer control for the motions of the X-Y table and the aperture head, auto focus, data transfer, etc.: all this means a user friendly operation. The repair station can be supplied optionally with a CD measuring system and 2D-image processing facility to support inspection and repair work.

The LRS 902 was designed to repair both opaque and clear defects of hard chromium reticles or other thin metal layers. For opaque defects the machine works like the LRS 901, the clear defects are repaired by Argon CW laser induced pyrolytic deposition. The metal films are deposited from a mixture of metal carbonyls onto the surface of the mask thereby satisfying the clear defect repair requirements. The deposited linewidth is 3-6 microns.

Two other laser based machines were developed: a computer controlled laser activated CVD (Chemical Vapour Deposition) system and a laser pantograph. The applied lasers were KrF excimers, with a wavelength of 248 nm.

8. CAD Programs

A GATEMAN gate array design system was developed in 1989-1990. The system

runs on an IBM PC/AT and solves the problem of physical gate array layout design including automatic placement and routing as well as interactive graphical editing. The system is currently being tested at two locations in Hungary.

9. Semiconductor Technologies

In the last two years a super-clean laboratory system was built for the semiconductor technology with all the necessary services. The cleanest area corresponds to Class 10 of the US FS 209/C standard.

An extension of the resolution into the submicrometer regime was realized by using new resist materials, as well as photoresist enhancement processing such as image reversal process, diffusion enhanced silicidation, post-exposure bake and UV stabilization. Image reversal with a specially designed novolak photoresist such as AZ 5214 E allows one to produce positive, vertical or inverse wall-angle of resist patterns. By means of this technique MESFET type microwave transistor and $LiNbO_3$ planar waveguide preparations were made.

10. Body Surface Mapping of Cardiac Potential Fields

Statistical properties of body surface potential distributions (BSPDs) were studied in clinically homogeneous large groups. Data were recorded by an optimal 32 electrode limited lead system, the whole thoracic BSPD was evaluated by the method of R.L. Lux (Univ. of Utah, CVRTI, Salt Lake City) and, finally, data were represented in the space of Karhunen-Loeve eigenvectors. Statistical results prove that classification schemes to be developed for automatic BSPD recognitions should not use the assumption of multidimensional normality [46].

Within-group variability of BSPD is mainly due to the variability of cardiac electric sources while the influence of volume conductor variability is significantly less. Variability due to measurement reproducibility was approximately half of the total variance [47].

Sample size requirements of multivariate class representations were studied by BSPD data and by computer generated data sets as a function of dimensionality. Sample size was considered adequate if the mean distance between two sample sets, taken from the same continuous multivariate distribution and projected onto the best separating direction, remained below a prescribed level. Based on the results, the Kolmogorov-type test of homogeneity has been generalized for multidimensional distributions [48]. The physical meaning of linear discriminants optimally separating dichotomies of BSPDs of clinically homogeneous groups was

characterized by the associated epicardial lead fields. Computations were carried out on a real shape numerical chest and heart model. The volume conductor was simplified to be homogeneous.

Judging from our experience, optimum linear discriminants are spatial filters, responding dominantly to cardiac sources on the anterior heart surface, where the between group differences are the most significant [49]. The clinical utility of BSPD analysis was demonstrated in comparison with Tl-201 scintigraphy in exercise tests [71].

Magnetic Anisotropy and Metallic Glasses

É. Kisdi-Koszó, Z. Vértesy, A. Lovas, L. Pogány, L. Potocky, P. Kollár, J. Kovác, L. Novák, M. Hrabcák, Z. Kaczkowski

The magnetization properties of ferromagnetic materials strongly depend on the anisotropy of the material. Amorphous ferromagnetic alloys are magnetically very soft partly because of the lack of crystalline anisotropy. On the other hand, they are more sensitive than crystalline materials to anisotropies of other origin. This is the reason why so much work has been devoted all over the world to investigating both the possibilities of how to produce induced anisotropy in metallic glasses and to investigating the resulting changes in magnetization properties. Some of our results are summarized in the following.

The magnetostriction of iron-based metallic glasses is very high so these alloys are sensitive to mechanical stresses. Depending on the sign of magnetostriction the stress fixes an easy magnetization direction either parallel or perpendicular to the strain . Therefore the magnetization direction inside a domain will more or less follow the direction of the existing strain in the material. The changes in structure of the magnetic domains due to the applied and released tensile stress in Fe-Cr-B metallic glass ribbons were observed in situ by scanning electron microscopy used in the back-scattered electron imaging mode [102]. The applied or released tensile stress was followed by an immediate change in domain structure, continued by small-scale changes over a long period of time. Of course these domain observations give direct information only on the surface. We established a correlation between the changes in the surface and the bulk properties such as coercive force and magnetic anisotropy resulting from heat treatment [68].

The possibility of achieving induced anisotropy depends on various heat treatments in appropriate magnetic fields or under mechanical stress. We used two special "heat treatments", namely casting of metallic glass ribbons in a magnetic field and pulse annealing under tension.

Fe-B-based metallic glass ribbons were prepared by melt-spinning in longitudinal and transversal magnetic field as well as without a field. The effect of the magnetic field applied during casting was studied in terms of magnetization, coercive force, magnetic anisotropy, Curie and crystallization temperature, domain structure [69] and magnetomechanical coupling [39].

It is perhaps curious to speak of "heat treatment" during quenching at a cooling rate of about 10^6 K/s. However, it was already shown earlier that some in situ heat treatment occurs during such a rapid quenching (i.e. the relaxation state of the quenched ribbon depends on the cooling rate). The influence of the magnetic field applied can thus be considered in situ heat treatment during cooling through the amorphous Curie temperature of the ribbon. Of course, some effect may also be attributed to the magnetic field acting on the melt during solidification. This latter assumption is supported by the observation that in spite of keeping all the quenching parameters constant, the geometry of the ribbons varied with the applied magnetic field: the ribbons quenched in a transversal magnetic field became significantly thinner.

The magnetization properties of Fe-B ribbons quenched in a magnetic field were investigated in [69] (and in another paper to be published in Anales de Física). The thermomagnetic curves taken on these ribbons show some small differences in the room temperature magnetization but the differences may be due to of the changing density. The Curie temperature is slightly higher for the samples prepared in a magnetic field than those without a field. Hence one may conclude that the magnetic field caused some changes in the structure. The crystallization temperature of the samples quenched in a longitudinal magnetic field was significantly lower than that of those quenched in a transversal field or without a field.

The direct measurement of induced anisotropy is not so easy as it is for the as-quenched ribbons. Both the induced anisotropy and the anisotropy due to quenched-in stresses are present. They have to be separated. If one combines stress-relief heat treatment with in situ anisotropy measurements the anisotropy decreases with increasing annealing time. This decrease is slower in samples prepared in a magnetic field than without a field. - Maybe the magnetic field acting during solidification decreases the quenched-in stresses. The ribbon quenched in a transversal magnetic field has the highest magnetic anisotropy after stress relief - there is really an induced transversal anisotropy in it. But this anisotropy is very low (14 Jm^{-3}). It seems that the applied field of 8000 A/m was not high enough. The magnetic domain observations reinforce the existence of induced anisotropy: in a ribbon quenched in a transversal magnetic field the domains are mainly transversally oriented whereas in a sample quenched in a longitudinal field only longitudinal domains exist.

The moduli of elasticity E_H and E_B measured at constant magnetic field and induction were investigated in [39]. The moduli of elasticity were determined from the resonant and antiresonant frequencies of the half-wave resonators, i.e. from the

investigated strips of length equal to the half wavelength cut from the metallic glass ribbon. The maximum magnetomechanical coupling of 0.42 was observed with a quality factor of 500 in the ribbon quenched in a transversal magnetic field; however also in ribbons quenched in a longitudinal magnetic field improved piezomagnetic properties were observed because of the induced anisotropy.

While investigating the effect of rapid annealing under tension we carried out pulse heat treatments in air using 0.4 s current pulses through the amorphous ribbon. With this technique one can apply higher temperatures without any crystallization than in ordinary heat treatment. All the pulse heat treatments could thus be done above the amorphous Curie temperature so as to avoid magnetically induced anisotropy. Heating and cooling rates were of the order of 1000 and 100 K/s [31]. The results of pulse annealing were monitored by coercive force and effective anisotropy measurements carried out between the pulses at room temperature. It was shown that pulse annealing generates a magnetically very soft relaxed state. If a mechanical stress of 128 MPa was applied along the ribbon axis during the pulse heat treatment a longitudinal induced anisotropy of 170 J/m^3 was achieved [44].

Epitaxial Growth of Gadolinium-Silicide Film on Single Crystal Silicon

G. Molnár, G. Pető, E. Zsoldos, J. Gyulai

The rare-earth (Gd,Er etc.) silicides grown on a single crystal silicon surface by solid phase reaction have attracted interest because of their low formation temperature (300-350 °C) and their low Schottky barrier heights on n-type silicon (~0.4 eV).

It was known that only one phase formed during the reaction between a rare-earth metal thin film and a single crystal silicon substrate, mainly with R.E.$Si_{1.7}$ composition, and with hexagonal AlB_2 structure. However, in the case of a gadolinium thin film and silicon substrate reaction, only the orthorhombic $GdSi_2$ phase was found. Previous studies had emphasized that Gd did not form an epitaxial silicide layer in the solid phase reaction (hexagonal $GdSi_{1.7}$ on <111> Si). This deviation in the findings was the basic motivation of our study. Investigations were made under different various conditions, e.g. at different temperatures of annealing and Gd layer thicknesses.

The silicide phases formed were identified by X-ray diffraction (XRD), RBS and Transmission Electron Microscopy (TEM).

In contrast to data published so far, on most of our samples we have observed both orthorhombic $GdSi_2$ and hexagonal $GdSi_{1.7}$ phases to exist simultaneously. The intensity ratios of the selected diffraction lines for the two phases showed systematic dependence on annealing temperature [J. Appl. Phys. 64(12), 6746 (1988)]

The phase appearing first was hexagonal $GdSi_{1.7}$ and the second one was orthorhombic $GdSi_2$. With increasing temperature the $GdSi_2$ intensity increased compared with $GdSi_{1.7}$. It was interesting to observe that the formation of the different phases strongly depended on the thickness of the Gd layer deposited on the Si surface. At thicknesses of 50 to 150 nm the dominant phase was orthorhombic $GdSi_2$. At 250 nm, the hexagonal $GdSi_{1.7}$ was the main component; in the 300-1000 nm thickness range, the orthorhombic $GdSi_2$ phase formed again.

The phases were mixed within the layer, and did not show any layer by layer growth.

Gösele and Tu [J. Appl. Phys. 53, 3252 (1982)] proposed a model by means of which one could understand these special features of the thin film silicide reactions if the phase formation is a layer by layer process.

This model proposes that for silicon-metal diffusion couples the compound phase having the lowest effective reaction barrier will grow first. When the source of metal or silicon is exhausted a different second phase will be formed at the cost of the first phase, depending on whether the metal or silicon source is cut off. Following this model, one can expect that the formation of the different phases depends on the amount of metal available, i.e. on the thickness of the metal film deposited on the Si surface. Nevertheless, in the case of Gd-Si diffusion couples the silicide layer did not show a layer by layer growth, but the reaction began along grain boundaries of the Gd. However, the model is also applicable for grain boundary growth, at least from qualitative aspects. Our experimental findings on the Gd-Si system are very well correlated with the Gösele-Tu model. At thicknesses of 50-150 nm most $GdSi_{1.7}$ transforms into $GdSi_2$. At greater Gd thicknesses - up to 300 nm - the first step of the reaction takes more time and only a small part of the $GdSi_{1.7}$ transforms into $GdSi_2$. As in our experiments the annealing was isochronal, various Gd layer thicknesses resulted in different ratios of phases.

This process is responsible for the formation of different phases and the uncertainties of the results obtained by other authors. In addition, it allows us to program the formation of different phases by the thickness, annealing time, and the temperature of the Gd films. Moreover, we are able to construct epitaxial layers of Gd-silicides on different orientations of Si substrates. It would seem that other authors were unsuccessful in doing the same because they were unaware of the different phases and the formation process and thus could not design the appropriate phase for their substrate. The epitaxy of orthorhombic $GdSi_2$ on δ Si was proved in our earlier paper [Appl. Phys. Lett. 51, 2144 (1987)].

The other possibility is the epitaxy of hexagonal $GdSi_{1.7}$ on *o* silicon [Appl. Phys. Lett. 58, 249 (1991)]. Since the Gd-silicide layers are formed with the silicon diffusing partly through grain boundaries, the formation of $GdSi_{1.7}$ is not a usual layer-by-layer growth. During the first period of growth, some misoriented hexagonal $GdSi_{1.7}$ will grow near the grain boundaries and far from the interface. This misoriented layer will disappear when the reaction from the interface reaches the surface to give a completely reacted film. Also, more than 4 minutes annealing for 250 nm thick samples at 600°C will result in the appearance of the second orthorhombic $GdSi_2$ phase both at the interface and along grain boundaries, while the epitaxy of hexagonal $GdSi_{1.7}$ will be destroyed.

In summary, it was demonstrated that a knowledge of the formation process of Gd-silicide layers from a gadolinium thin film and a silicon substrate give the key to the "engineering" of epitaxial Gd-Si compounds.

Properties of an Heavy-Ion Implantation Induced Anomalous Amorphous Germanium

G. Pető, L. Rosta

It is generally accepted that amorphous Si and Ge have a very slightly modified tetrahedral short range order compared with crystalline Ge or Si. Many unsuccessful attempts have been made to find a state basically different from these "normal" amorphous states.

One of our earlier work [G. Pető, J. Kanski, S.S.C. 1980] had suggested for the first time that ion implantation can induce an amorphous state of Si with an electronic structure markedly different from the well-known normal amorphous Si. We proved this suggestion for a-Ge induced by $^{121}Sb^+$ implantation [G. Pető, J. Kanski, U. Södervall, Phys. Lett. 1987].

To exclude the role of impurities such as Sb, C, O implanted directly or via knock-on into the implantation induced amorphous Ge, we investigated the effect on a-Ge induced by self implantation in ultrahigh vacuum [63]. Self implantation in ultrahigh vacuum induced an amorphous state of Ge which is,from the electronic point of view, very similar to $^{121}Sb^+$ implantation in normal vacuum. It is thereby shown that the extraordinary amorphous state induced by heavy ion implantation is an intrinsic one.

Moreover, since the UPS spectra - in particular the density of states - gradually change in the damaged layer of the ion implanted surface, one may conclude that there exists a series of extraordinary amorphous states of a-Ge which significantly differs from the well-known amorphous Ge.

To understand this anomalous state of a-Ge, further electronic and structural investigations were pursued with the aim of correlating this extraordinary state with the phase of Ge that can exist only under extreme conditions, e.g. in the liquid state.

These properties were measured by transmission electron microscopy (TEM), neutron diffraction and photoemission (UPS). First, a model experiment was carried out on evaporated a-Si, which is much more reactive than Ge, with a comparable quantity to the measurable implantation induced a-Ge to test our experimental and sample preparation facility.

The structural data obtained by us [50] fit well the theory and the published experimental data [J. Fortner and J. S. Lannin, Phys. Rev. B 39, 5527 (1989)]. This ensures that the experiments and sample preparation are artifact- free, even at this extreme condition of neutron diffraction. For the neutron diffraction measurements, evaporated and ion implanted (anomalous) a-Ge was used and the UPS and TEM investigations were carried out on evaporated (normal) amorphous Ge, on evaporated and ion implanted (anomalous) a-Ge, as well as on evaporated ion implanted and annealed (crystalline Ge) samples, in order to find references.

Since the sets (anomalous amorphous, normal amorphous and crystalline) of TEM patterns are sufficiently different, a significant structural difference between the normal and anomalous a-Ge is unambiguous from the viewpoint of both morphology and structure.

The neutron diffraction results allow, despite the relatively large statistical error due to the small sample mass, some qualitative conclusions that reinforce the deductions from the TEM data, namely that the maxima and widths, respectively, of the first three major peaks at 1.9, 3.4, and 5.5 $Å^{-1}$ decreased and increased by 20 to 40 %. Moreover the intensity ratio of the first and second (0.6) as well as that of the second and third maxima, (1.6), are smaller than the corresponding data, 0.7 and 2.3, for normal a-Ge.

The first neighbour distance (2.5 Å) and average density (0.04 atom/$Å^3$) are slightly different from the normal a-Ge. It is thus clear that the neutron diffraction results on ion implantation induced anomalous a-Ge are definitely not equivalent to data of normal a-Ge. The structure of this anomalous a-Ge is obviously modified towards the liquid state of Ge.

The modification is confirmed by the deformation of the electronic structure, which, for anomalous a-Ge, shows some similarities with the calculated density of states of liquid Si. The ability to accomodate Ar into the specimen during Ar ion bombardment is much greater for normal a-Ge than it is for anomalous a-Ge, indicating indirectly that the latter is somewhat more dense and liquid-like in this sense.

So far as the density of states at the Fermi level is concerned, although the valence band is somewhat broadened we did not find a measurable intensity at the Fermi level: this indicates that this implanted amorphous Ge remains a semiconductor.

There are indications that the structure of a-Ge induced by heavy ion implantation is anomalous and that it is intermediate between the normal amorphous state and liquid Ge. Moreover, this conclusion does not concern a single phase. Doubtless, a whole series of similar phases exists. We believe that our

experimental data present the first indication of an anomalous amorphous germanium with a short range order that basically differs from tetrahedral. This expectation, however, contradicts the generally accepted view.

Transport-Driven Reorientation

Gy. Szabó

In lattice-gas models the *ordered state* always has some degeneracy corresponding to the symmetry which is broken upon the transition. The particle distribution may become anisotropic there in spite of the cubic symmetry of the host lattice. For example, the particles can form parallel chains along one of the crystallographic directions. In this case the ordered states specified by chain orientation are equivalent. In the presence of an electric field, however, the equivalence between the principal directions is no longer valid. This situation raises the question whether applied fields prefer one of the degenerate states and if yes, which one.

This question is of importance for a large variety of systems. For example, in a family of superconducting oxides (1:2:3 compounds) Cu-O chains are formed with two possible orientations. Theory suggests anisotropic particle distribution in other two-dimensional lattice-gas models introduced to describe phenomena in monolayers at surfaces. Anisotropic silver distribution is expected to appear in the superionic phase of AgI. Furthermore, a very similar symmetry breaking is observable in the formation of antiferromagnetic spin density waves along one of the cubic axes in chromium.

We have studied a square lattice with repulsive interactions of equal strength between nearest- and next- nearest neighbours. This model is not directly applicable to any real system. Nevertheless, its choice is reasonable for a detailed study of the static properties and kinetics of the ordering process. The system undergoes a continuous order-disorder phase transition at a critical temperature. In the ordered phase of the half-filled lattice the rows (or columns) are alternately occupied or empty. Consequently the ground state is fourfold degenerate. The stochastic dynamics of the system is described by the Kawasaki mechanism characterized by single particle jumps to one of the adjacent empty sites. The jump rate is affected by an electric field parallel to one of the principal axes. In equilibrium (no electric field) the self diffusion is anisotropic because the chain structure selects a preferred direction for the particle motion.

Monte Carlo simulations have proved that in the stationary state the chains prefer the orientation parallel to the applied field. In other words, the chain orientation may be modified by applying an electric field of suitable direction. The real time monitoring of the particle distribution illustrates that the reorientation process is analogous to the recrystallization including nucleation and the growth of

preferred domain(s). The rate of reorientation depends on both temperature and the strength of electric field. Obviously, the stronger the electric field the faster the orientation process. At increasing temperature and fixed value of the electric field the reorientation becomes faster. This effect may be explained by the higher diffusion and the increasing role of fluctuations in the close vicinity of the order-disorder phase transition. Namely, the appearance of preferred domains that have sufficiently large size is more probable at higher temperatures. These results agree qualitatively with those extracted from simple mean-field approximations.

Below the critical temperature the long range order is described by dividing the lattice into four sublattices. Within the framework of a four sublattice approximation the Kawasaki dynamics defines the time derivative of the sublattice occupations. The stationary solution of these equations allows us to distinguish between states of chains parallel and perpendicular to the applied field. Significant differences are observed in the temperature dependence of sublattice occupations when choosing the electric field parallel or perpendicular to the chain direction.

In thermodynamic equilibrium the stable state is determined by the minimum of the free energy. Unfortunately, in the presence of an electric field we are not able to define an adequate "nonequilibrium free energy" to be minimized. This difficulty is circumvented by a standard linear stability analysis, which has justified the stability of the states consisting of chains parallel to the electric field. It is found that the perpendicular orientation is not stable in the close vicinity of the critical temperature. In agreement with the Monte Carlo simulation, however, this orientation may be considered as a metastable state at low temperatures. The exact solution of the master equation on a 2x2 lattice confirms the above conclusions.

The reorientation process is also demonstrated in a lattice-gas model introduced to describe the oxygen ordering in certain superconducting oxides. Thus, this transient non-equilibrium process may be of relevance to the properties of these compounds.

Our work is concentrated on theoretical investigations of the reorientation process, the existence of which has not yet been confirmed by experiment. The above results obtained in a square lattice may involve similar phenomena in three-dimensional systems because the reorientation process is closely related to the anisotropic diffusion (or conduction) generated by the symmetry-breaking particle distribution. The latest experiments have indeed proved the existence of a partially disordered state in AgI. The anisotropic character of this state has already been cleared up by previous theoretical calculations. This is the reason that AgI is considered as a candidate for inclusion in the experiments.

Our understanding of the statistical physics of nonequilibrium phenomena is much less satisfactory at the moment. No general suggestions are available for choosing appropriate ensembles, not even for the simplest nonequilibrium systems, e.g. the driven lattice-gas models. It is to be hoped that the present work will stimulate both theory and experiments in this field.

Effect of Sample Size on the Coercivity

G. Vértesy, L. Bódis

It has been observed that, in epitaxially grown magnetic garnet layers, the domain wall coercivity measured by the wall-oscillation method on both stripe and bubble domains significantly decreases with sample size, decreasing from 2000 to 5 mm^2. Meanwhile, the bubble collapse field was found to decrease by a few per cent. Other parameters proved to be independent of sample size.

Coercivity and collapse field are related to sample dimensions via the sample-size-dependent derivatives of the total free energy with respect to domain wall positions. Even a small change in the slope of the potential wells at the domain wall - i.e. a change in the free energy derivatives - may cause an appreciable variation in the domain wall response to the applied field, and thus in the coercivity measured by wall-oscillation.

We wished to clarify whether the observed dependence of coercivity on size is sensitive to the given measurement method or wether it reflects an intrinsic property. The other purpose was to investigate in more detail how the existing mechanical stresses in the crystal affect the magnetic parameters [97].

Epitaxial garnet films $(YSmCa)_3(FeGe)_5O_{12}$ were used for the measurements. Films were grown by liquid phase epitaxy LPE on {111} oriented $Gd_3Ga_5O_{12}$ GGG substrates.

The coercivity of the epitaxial garnet films was measured by various methods. Detailed investigations showed that the lower value of coercivity in the case of stripe domains as compared with the coercivity of bubbles or finger-like domains was caused by the stronger interaction of neighbouring domains. The same interaction is almost completely eliminated in the case of thin bubble lattices or finger-like domains. These results indicate that the coercive field values determined by wall-oscillation methods can be considered to well characterize the interaction between domain wall and defects. On the other hand, non-oscillatory (wall translation) methods, e.g. the domain expansion, bubble translation and hysteresis loop methods seem to involve technical parameters, resulting in a description which is not generally applicable to the material as a whole.

The effect of sample size was found characteristic only of the domain wall coercivity measured by wall-oscillation methods. Neither the domain expansion nor the bubble translation or classical hysteresis loop methods showed any dependence of the coercivity on sample size.

The oscillatory methods were evidently sensitive to distribution and local shape of the stray fields at the domain wall sites (being themselves influenced by sample size) as the walls "rock" in their potential wells during the measurements.

The coercivity can be affected by mechanical stresses in a magnetic body via the magnetoelastic interaction. The coercive field intensity is proportional to the local changes in the domain wall energy and, in this way, it is a function of local changes in the total anisotropy energy. In epitaxial garnets the anisotropy is a combination of the cubic crystalline anisotropy K_1 and the uniaxial anisotropy K_u, which is composed of a growth-induced and a stress-induced part. The main stresses in epitaxial garnets are due to a film-substrate lattice mismatch. The correlation between uniaxial anisotropy constant and film-substrate lattice mismatch is given by magnetostriction.

However, this stress is expected to be independent of sample size and it cannot be relaxed by cutting the sample. On the other hand, calculations show that the substrate itself contains mechanical stresses which are due to thermal conditions during Czochralski crystal growth, and which can be modified by cutting the sample. In principle, this can influence the coercivity, and can cause H_c to be size dependent.

Measurements show that the uniaxial anisotropy is independent of sample size: K_u is practically constant in a wide range of sample sizes while the change in coercive field is considerable. The question arises as to whether K_u is a sufficiently sensitive indicator of changes in stress, or whether coercivity owing to a change in stress fluctuation may be modified without any measurable difference in K_u.

The substrate was thinned in order to modify the film-substrate lattice mismatch, and to obtain an empirical connection between stresses and magnetic parameters. The coercivity definitely decreases with stress relaxed by thinning the substrate. The uniaxial anisotropy changes in a similar way indicating a close correlation between coercivity and anisotropy. It is believed that this measurement proved the anisotropy to be a sensitive parameter for indicating changes in the mechanical stresses within the film, and that a certain change in the stresses, which causes a measurable difference in coercivity, leads also to a measurable change in anisotropy.

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USER'S MANUALS

- TELECONT User's Manual
- Remote Control Protocol for the Integration of the TELECONT According to the SEMI 1990 Standards
- FRG 512 Frame Grabber User's Instruction
- Data Sheets of the Programable Step-motor Controller

EXHIBITIONS

- EUREKA (1989 Spring, Vienna): Escort of the late TELECONT
- International Technical Exh. (1989, Dusseldorf, W. Germany): Autofocus unit
- International Trade Fair (1990, Hannover): Complex CD measurement system
- SEMICON (1989,1990,Zurich): TELECONT system, autofocus unit, step-motor driver, frame-grabber

KFKI ATOMIC ENERGY RESEARCH INSTITUTE (AEKI)

One of the main features characterizing the activity in our Institute is the integrity of the interconnected fundamental, applied, and engineering research. Another feature is the attempt to cover all important fields of reactor safety which is, on the one hand, the result of tradition and, on the other, the consequence of the careful selection of the research topics. As a result, the underlying structure behind our activity displays some diversity but even so, the different topics are integrated into one large framework.

This complex way of problem handling permitted the realization of a code package describing the coupled thermohydraulics and neutron physics for simulating the core of the WWER-1000 type power reactors. Tasks of this magnitude have so far been accomplished only in the developed Western countries. Application of the code package for the WWER-440 core of the Paks Nuclear Power Plant (NPP) has just begun.

Based on some basic research on thermohydraulics, procedures and methods were developed so that the Paks NPP could ensure safe and economic operational procedures. By using the PMK-NVH facility (a high-pressure loop for modelling Paks operations) investigations were extended to include all primary circuit processes. Based on this experience, we were able to provide help for the Paks NPP during the stage of improving safety performance required by the authorities.

Another field included the topics of power plant simulators and diagnostics where the efforts of groups working on reactor physics, thermohydraulics, neutron and process noise, and acoustic emission problems were integrated. This engineering effort included the installation of basic principle and full-scale simulators and diagnostic systems in the Paks NPP in Hungary, and in the Kola, Rovno, and Kalinin power plants in the USSR.

Internationally acknowledged results were obtained in health physics in the fields of stochastic lung models, dosimetry, and natural background radiation exposure assessment.

Internationally acknowledged results were obtained in health physics in the fields of stochastic lung models, dosimetry, and natural background radiation exposure assessment.

Traditional and very satisfactory fundamental research includes physico-chemical work on the molecular structure of condensed systems, on the solid/liquid interface, and on several aspects of nuclear chemistry.

Foundations were laid for a nationwide system of monitoring the environment based on nuclear, health physics, chemical, and software components, thus offering a truly up-to-date possibility for advanced problem handling and management.

Reactor Analysis

The purpose of research into reactor physics was twofold. One field included the development of the algorithms for describing the neutron physics of the reactor core. Experimental work was also in progress to test and improve the results of the calculations.

A new calculation scheme was worked out and tested against the measurements performed on the ZR-6 zero-power critical assembly. The new model includes a refined network calculation of the reactor lattice and, in contrast to the diffusion calculations used so far, incorporates a method based on the response function of the individual fuel bundles.

The development of the KARATE program system which performs process calculations for the WWER-1000 reactor was successfully completed. In particular, a code package was created which is capable of performing detailed calculations on the coupled neutron physics and thermohydraulics of the reactor core at the power plant. The development targets were modified in 1990 to enable the code to be utilized for WWER-440 units.

Measurements on the ZR-6 zero-power critical assembly were aimed at testing the calculation procedures described above, and at improving their precision. These measurements have been perforemd since 1975 within the framework of an international cooperation scheme. The experimental part of the programme ended in 1990.

Thermohydraulics

Based on an integral-type mock up facility, a wide range of experiments assuming small and medium scale cold-leg breaks was performed as required for the safety assessment of the assumed emergency situations that might arise at the Paks NPP.

In cooperation with the International Atomic Energy Agency, (IAEA) the project of the third Standard Problem Exercise was organized to test the available codes.

Based on our theoretical and experimental results on core thermohydraulics, methods and procedures were worked out for the hot-channel based operation mode.

Applied Reactor Physics

Research into applied reactor physics included the monitoring of the reactor core and the primary circuit, and the processing, evaluation, and display of the signals from these sources. As a result, on-site reactor monitoring systems were generated along with software packages for modelling and numerical simulation.

Based on an order placed by the Kurchatov Atomic Energy Research Institute, Moscow, a data acquisition, information and operator advisory system was developed for the Soviet MR material testing reactor facility.

Theoretical and methodological investigations, making use of filter theory, were performed and a demonstration system was created to detect and identify malfunctioning power plant sensors.

The work on real-time power plant information and advisory systems was continued.

Noise Diagnostics

Relations between the cross spectra of the reactor core hot spots and the in-core neutron detectors were clarified.

An algorithm and a software package were developed to describe reactor core motions.

A code package for multidimensional autoregression was written.

The connection between the low-frequency pressure fluctuations and the water level fluctuations in the volume compensator unit was proven theoretically and experimentally.

For the Kalinin power plant we developed a complete noise diagnostics system.

Reactor Simulators

In the field of the dynamic simulation of nuclear reactors, we participated in the development of the full-scope simulator of the Paks NPP, in the elaboration of its acceptance criteria and in carrying out the acceptance tests.

A simulation environment was created around TPA-11-type computers, and a dynamic model system for WWER-440 nuclear power plants was developed.

By combined research and engineering efforts, three power plant simulators were completed: the basic principle simulator for the Paks NPP, and two compact simulators - one for the Kola NPP and the other for the Rovno NPP (USSR).

Health Physics

Methods were developed to determine radiation burden, since for the population the main source of radiation exposure is that emitted from the walls of buildings. Three methods were applied to determine the radiation field.

In the development of thermoluminescent dose monitor read-out units the most important step consisted of the construction of a semi-automatic device which is capable of reading the bar code of individual dose monitors. It automatically takes into account the individual sensitivities and stores the data in a computer-readable format.

In the course of the development of the stochastic lung model, a complete model of the human respiratory system was created. The random walk and the deposition of inhaled particles can thus be studied more precisely.

Published biological models for iodine metabolism were compared with those described in the ICRP dosimetry model. We concluded that the iodine incorporation dose depends basically on the retention and on the mass of the human thyroid gland.

In the follow-up studies of the Chernobyl accident, Cs-137 activity concentration was measured in breast-milk and in nursing mothers. Temporal changes of the total Cs incorporation caused by the Chernobyl accident were estimated on the basis of whole-body counter experiments.

Fracture Mechanics and Radiation Damage

For assessing the safety of reactor vessels it is important to know the fracture mechanical properties corresponding to the actual thick-wall material, and to the actual temperature. The aim was to determine these material properties on radiation-damaged steel and aluminium samples.

We have been participating in the programme "Optimization and evaluation of the periodic control procedure of reactor vessels" organized by the IAEA since 1984. This programme is scheduled to be completed in 1992, when recommendations will be agreed upon. The aging of reactor vessels and their projected useful lifetime will be determined on the basis of these recommendations. As an appreciation of our previous work, the creation of the data base for the full IAEA project became our responsibility.

Acoustic Emission

The importance of non-destructive material testing methods continues to increase, especially in the nuclear industry. Our Institute has been active in the last fifteen years in acoustic emission measurements based on the detection of stress-produced ultrasonic signals emitted by faulty regions in the test structures. Failures such as fractures, leakage, or microscopic cracks can thus be detected.

Our work included methodological and signal interpretation research, measurements in industrial environments, and development of measuring instruments and software. The main fields of activity can briefly be summarized as follows.

- regular acoustic emission monitoring during the periodic pressure tests on the reactor vessels of Paks NPP;
- acoustic emission control of industrial structures;
- development of an up-to-date acoustic emission measuring instrument family with the associated software (the Defectophone), which is competitive on the international market.

Analytical Chemistry

Research efforts were concentrated in two main directions: development of nuclear methods and mass spectrometry.

To expand the range of applicability of neutron generators, a new measuring system was created to measure short-lived isotopes. We proved experimentally that the application of binomial distribution instead of the usual Poisson one might become necessary if the measurement time is longer than the half-life of the isotope studied.

A new mass spectroscopy method was developed and is now used as a matter of routine for analysing ultramicro quantities. Theoretical work included the study of creation and propagation of laser-induced plasma. The depth of the laser-burnt hole and the energy of the emitted ions - as calculated by a one-dimensional model - agreed well with the experimental data.

In the environmental protection project, the toxic components of fly ash produced by Hungary's coal-burning power plants were investigated. An instrument capable of measuring sulphur dioxide emission rates was also constructed.

Chemical Physics

Solid/liquid interfaces, the molecular structure of condensed systems, and non-solvated, highly energetic and thermalized halogen atoms were the main research topics.

In electrochemical kinetics, theoretical and experimental tools were used to generalize the conventional equations for describing fractal interfaces.

Dielectric relaxation and electron transport in polar liquids were studied by invoking theoretical models.

The structure of thin interfaces containing ferrous oxides was determined by using conversion electron Mössbauer spectroscopy.

Results obtained for the structure and for intermolecular interactions in condensed systems can be summarized as follows.

The potential describing the molecular vibrations of triply halogenated methane derivatives in the condensed phase is determined basically by the intermolecular distances. Our theory for describing the deviations from the ideal behaviour of isotope mixtures was verified by measurements performed over a wide range of temperature and concentration.

Results in the field of studying micellar systems by small-angle neutron scattering, positron annihilation, and thermodynamics include the derivation of a closed, analytical formula for describing the apparent and partial molar volumes of the surface-active molecules in micellar solutions. Decomposition of the positron lifetimes in these solutions was done by a new algorithm.

Halogen atoms produced in nuclear reactions of small recoil energy were shown to produce a short-lived transition complex after the atom-molecule collision in their substitution reactions with aromatic compounds. The addition reaction of astatine to ethylene was proven to take place, and the reaction kinetics and the pH-dependence of the product yield were determined.

Space Electronics

Development and production of space electronics devices has been one of the successful fields in our Institute for over twenty years, and significant results have been achieved in several missions (IK-satellites, 'Vertikal' rockets, the programmes of Prognoz, VEGA, and Phobos).

In the PHOBOS programme, operation and data processing of the "Harp" low-energy electron detector and the "Taus" ionic spectrometer, on board the Phobos probes to Mars, were continued.

In the MARS'94 programme, detector electronics was developed and tested for the "Maremf" electron spectrometer scheduled to fly on board in the 1994 missions to Mars.

Spin-offs from space electronics development included on-board diagnostic and data acquisition systems for aircraft engines. These systems have been installed on several of Malév's (Hungarian Airlines) TU154-type aircraft.

Research into Severe Reactor Accidents

The project investigating core meltdown accidents was started in 1990 with the installation and the successful application of the American Source Term Code Package. Calculations for severe accident processes were tested in the international Standard Problem Exercise ISP-28.

Environmental Protection Research

Functional design specifications for remotely operated radiation detector stations were laid down. It is planned that, in addition to providing gamma-ray dose rates, the stations should measure and relay meteorological data.

A mobile dosimetry laboratory was developed for the on-site assessment of accident radiation levels in emergency situations. The fast, accurate and complete analysis may well provide the basis on which decisions to minimize the radiation exposure of the population are made.

Ion-Electron Pairs in Condensed Polar Media Treated as H-Like Atoms

Robert Schiller

Journal of Chemical Physics **92**, 5527 (1990)

One of the earliest observations on the interaction of high energy corpuscular or electromagnetic radiation and matter was on the formation of electric charges under irradiation. Subsequently the dynamics of charge generation and recombination was seen to obey non-conventional laws of transport. The reason for this has been understood to be twofold: (a) the charge carriers are produced at a higher-than-thermal energy, hence their energy loss to medium must also be considered; and (b) they are, initially, distributed inhomogeneously in space, mainly because positive and negative carriers are being produced in pairs and formed along particle trajectories. More recently, it has also been realized that (c) the negative charge carrier is most often an electron the behaviour of which cannot be treated in classical terms. It is also clear that the dynamics becomes particularly involved if (d) the matrix is a condensed polar phase where polarization interferes with charge transport in a somewhat complicated manner.

No theory is known at present that could consider all these factors in a consequent and rigorous way. Here we propose a model of low-energy (*ie* below 1 eV) ion-electron pairs to describe the moderation and self-trapping of electrons and recombination of ion-electron pairs in polar media. A discrete ion-electron pair is regarded as a ground-state H-like atom, which interacts with the medium through polarization forces and by experiencing energy fluctuations. Electron states and energies are calculated just as for a steady state H-atom with the difference of the Coulomb field being screened here by the polarization forces in the liquid.

Slowly relaxing polarization causes electron energy decrease on the time scale of constant-charge (also called longitudinal) dielectric relaxation. The rate of electron moderation was found to agree with earlier estimates. Owing to instantaneous polarization, a strongly attracting potential well is formed immediately upon ion pair formation.

Since an H-like atom is a stationary entity the electron can escape its positive partner only at the expense of some external energy. This ionization energy is thought to stem from thermodynamic fluctuations in the liquid. It is shown that fluctuations can assist the electron in escaping from the field of the ion, thus the electron is already self-trapped when moderation and escape take place.

The yield, *ie* the formation probability of radiation-produced solvated electrons, was evaluated for a series of polar liquids in terms of this polarization-fluctuation model:

$$\text{yield} = 5.4 \cdot 1/2 \cdot \text{erfc}(-2E_1/\sigma) = 2.7 \cdot \text{erfc}\left(3.04 \cdot 10^3/\varepsilon^2\sqrt{c}\right)$$

where *erfc* denotes the complementary error function, E_1 is the ground state Rydberg energy of the H-like atom at equilibrium polarization, and σ is the root mean square energy fluctuation. The second line refers to room temperature and shows explicitly the material constants upon which the yield depends, such as the static relative permittivity ε_s, and the specific heat c. The constant 5.4, denoting the yield of primary ionizations, was found by curve fitting. The

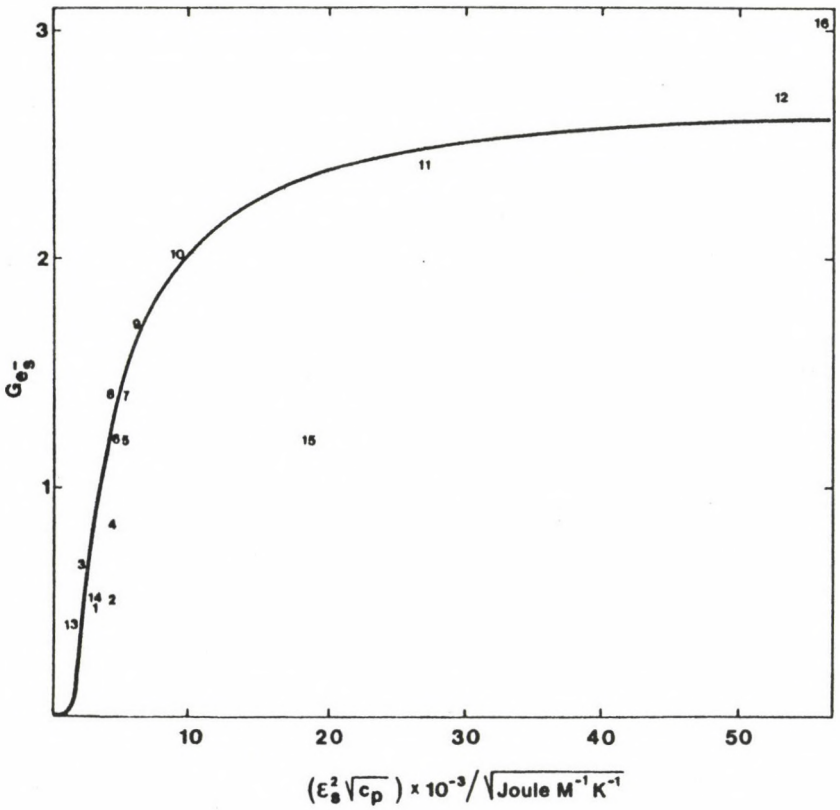

Fig. 1

Dependence of solvated electron yield on static permittivity ε_s and specific heat c_p. The continuous curve as predicted theoretically with $G_0 = 5.4\ (100\ \text{ev})^{-1}$. Experimental points: 1 – 1-pentanol, 2 – *iso*-butanol, 3 – tertiary butanol, 4 – 2-butanone, 5 – acetone, 6 – 2-propanol, 7 – 1-butanol, 8 – 1-propanol, 9 – ethanol, 10 – methanol, 11 – hydrazine, 12 – H_2O, 13 – pyridine, 14 – ethylenediamine, 15 – ethylene glycol, 16 – D_2O. For references see the original publication.

computed curve, together with a series of experimental data, is plotted in Fig. 1. The agreement, achieved by fitting a single proportionality factor only, seems to be reasonable.

Further refinement of the model enables one to explain the difference in electron yields for liquids and solids. An analogous treatment of non-polar substances is in progress.

Electrochemistry at Fractal Surfaces

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Chemistry Department, Institute for Atomic Energy Research

The laws and concepts of electrochemical charge transfer kinetics have been introduced or derived by assuming some simple (*eg* planar or spherical) geometry, which is not justified in the case of rough, porous or partially active electrode surfaces. These irregular interfaces are frequently modelled as fractals [see Ref. 1]. These models describe two different situations: the blocking interface and the case of the diffusion-controlled chemical reaction.

The blocking interface due to the absence of chemical reactions responds to an external potential perturbation by a transient (displacement) current, which is a consequence of the charge distribution relaxation in the electric double layer. The impedance response can, in general, be calculated by calculating the potential distribution. If the surface is of very complex shape this is a practically impossible task. However, if certain symmetries exist, approximations are available. For fractal surfaces, the impedance response is described by the so-called constant phase impedance (CPI) which is a power-law function of the frequency Ω, *ie* it is proportional to $(i\Omega)^{-\alpha}$ with the exponent being a non-integer number between 0 and 1. Based on this, many theories have been proposed (including our first attempt [see Ref. 2]) to relate the frequency exponent α to D_f, the fractal dimension of the interface. The different theories corresponded to different (implicit) assumptions and the results were apparently in conflict with each other. As our general treatment [see Ref.3] showed, the symmetry properties (self-similarity or self-affinity) of fractals allow us to construct the scaling laws for the relevant relations and quantities. Based on an analysis of the scaling laws, two fairly general equations were obtained relating α to D_f (and additional geometry parameters). More than a dozen of the published models were shown to yield results which are special cases of our general equations. However, due to technical difficulties, these equations cannot be used unambiguously for experimentally determining of the fractal dimension of real surfaces.

This can be done, however, by analysing the time dependence of the diffusion-controlled currents to fractal interfaces. Let us assume an interface between a metal and an electrolyte from the bulk of which molecules can diffuse to the interface. Let the interface be completely inert and reactive before and after time zero, respectively. Under such conditions the current is determined by the flux of molecules to the interface. Were the interface planar, the current would be

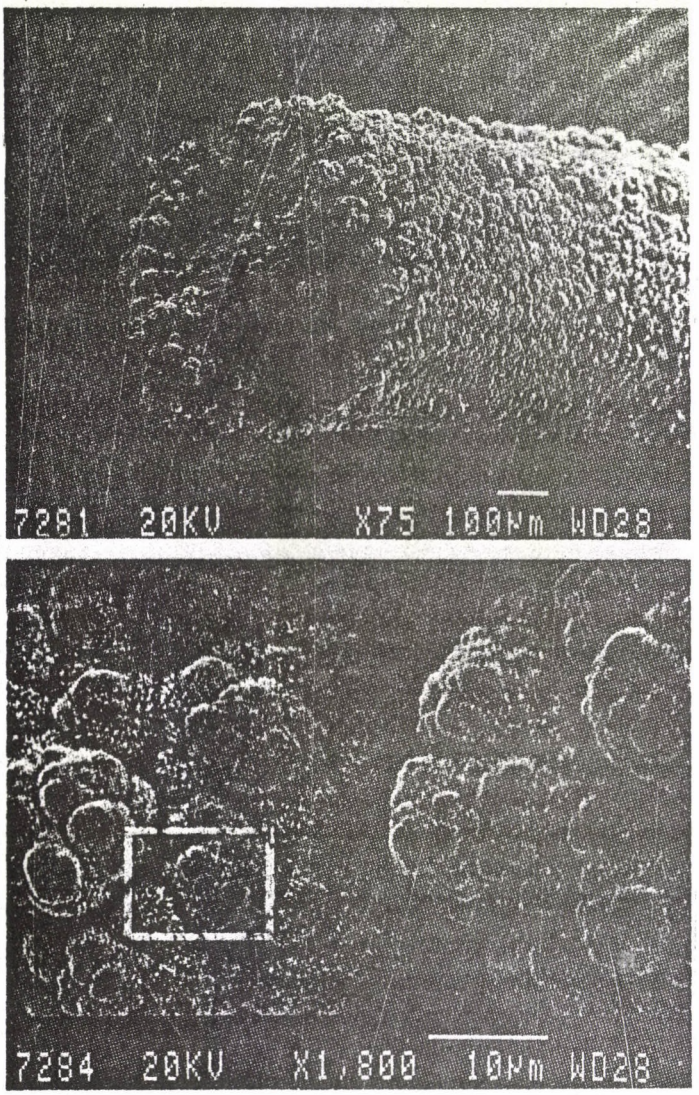

Fig. 1
SEM pictures of roughened platinum wire tip.

proportional to the inverse square root of time. In the case of a fractal interface the current is proportional to $t^{-\alpha}$ where $\alpha = (D_f-1)/2$, irrespective of the actual shape of the interface. In a recent publication [see Ref. 4], we have analysed the practical consequences of this one-to-one correspondence between and D_f.

As an application, we show on a real system (rough platinum, Fig. 1) how a surface can be characterized by using fractal concepts and electrochemical techniques. By using the above *vs* D_f equation, the fractal dimension of the rough platinum sample was determined in the 1 to 100 μm size range (Fig.2).

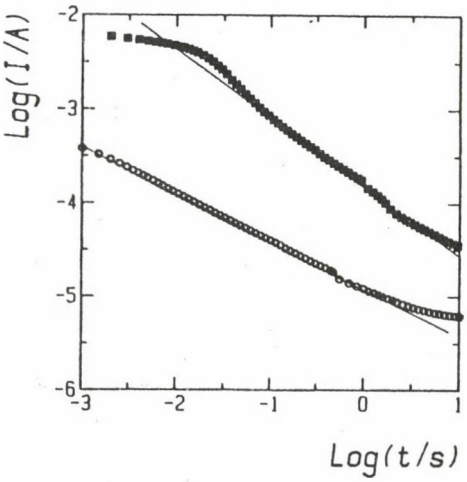

Fig. 2

Time dependence of transient current on a smooth platinum wire (a) and on a roughened one (b). The solid lines are drawn with the slope of -0.5 and -0.73, corresponding to $D_f = 2$ and $D_f = 2.46$, respectively.

Conclusions

1. If a blocking, capacitive electrode is of fractal geometry then the electrode impedance will be of CPI form. By using scaling laws the actual α *vs* D_f relation can be derived which, however, is not suitable for practical D_f determination.

2. The time dependence of the diffusion limited flux to a fractal surface is a power-law function of time, and there is a unique relation, $\alpha = (D_f-1)/2$, between the fractal dimension and the exponent α. This equation provides a possibility for experimentally determining the fractal dimension.

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Monitoring Environmental Pollution : Solid Waste from cOal-fiRed poWer plaNts

Rózsa Fliszár-Baranyai, H. Rausch, Ibolya László-Sziklai, Szvetlana Sándor, Szabina Török, and Éva Papp-Zemplén

Coal fly-ash is one of the most widely studied pollutants. The size, the morphology, and the chemical composition of fly-ash particles may vary considerably. Assessment of the potential environmental and toxicological effects of fly-ash pollutants therefore requires their detailed physical and chemical characterization.

The emission of black coal fired power plants has been discussed in several studies. Much less clear is, however, the chemical composition of the toxic products stemming from second or third class brown coal and lignite fired power stations typical in central eastern Europe including Hungary where about 30 per cent of the electricity is still being produced by coal fired power plants.

The aim of the present programme is to study the behaviour and the distribution of toxic components in various fractionated fly-ash samples collected at different locations. Sampling covered the four main power stations in Hungary (viz. Ajka, Borsod, Mátra, and Pécs) representing diverse locations and different fuel quality. The different fractions the bottom-ash, the electrofilter-deposited fly-ash and the fly-ash collected from the flue-gas at the top of the stack were collected and analysed separately. Measurements were performed both on the bulky substance and on individual particles. To calibrate the various analytical methods, standard reference materials such as NBS SRM-1633a coal fly-ash and IAEA SOIL-7, were used.

For the physical characterization of the individual fly-ash particles, optical microscopy, density measurements and particle sizing were used. Their chemical composition was determined by X-ray fluorescence spectroscopy (XRFS), spark source mass spectroscopy (SSMS), neutron activation analysis (NAA), and by inductively coupled plasma-atomic emission spectrometry (ICP-AES). The composition of individual particles was studied by scanning electron microscopy with micro X-ray fluorescence analysis (SEM-MXRFA).

Essential physical properties of the fly-ash matter include its particle size distribution, average density, specific surface area and morphology: these are seen to be correlated with the chemical properties such as composition and leachability. Optical microscopy-based image analysis has demonstrated that the fly-ash matter collected from the Borsod and the Mátra power stations shows a wide particle size distribution while fly-ash from Ajka and Pécs is characterized by a large amount of fine aerosol fractions due to the combustion technology and temperature (1400 to

1600 °C) used in the two latter plants. In a similar manner, the morphology of the various kinds of fly-ash substances seems to be primarily determined by the mode of combustion, which basically differs for lignite and for brown and black coals.

Knowledge of the specific surface area of the various fly-ash particles may be helpful in explaining the pronounced differences in the quantities of the volatile chemical components found among the different fractions. This is tentatively attributed to different sorption processes taking place in the flue gas.

Distribution ratios were calculated for selected toxic elements between the various fractions and the homogenized electrofiltered fly-ash with the latter serving as a reference. In accordance with the recommendations of the IAEA Research Coordination Meeting (Jakarta, 1989), 16 toxic and two radioactive elements (V, Cr, Mn, Ni, Cu, Zn, Ga, As, Se, Mo, Cd, Sn, Sb, Hg, Tl, Pb, Th, and U) were selected and studied thoroughly. Most elements (*cf.* Figs 1 and 2) show an increased concentration in the fine fractions. The observed enrichment of the volatile compounds is probably caused by a surface layer on the particles, which layer acts as condensation nuclei.

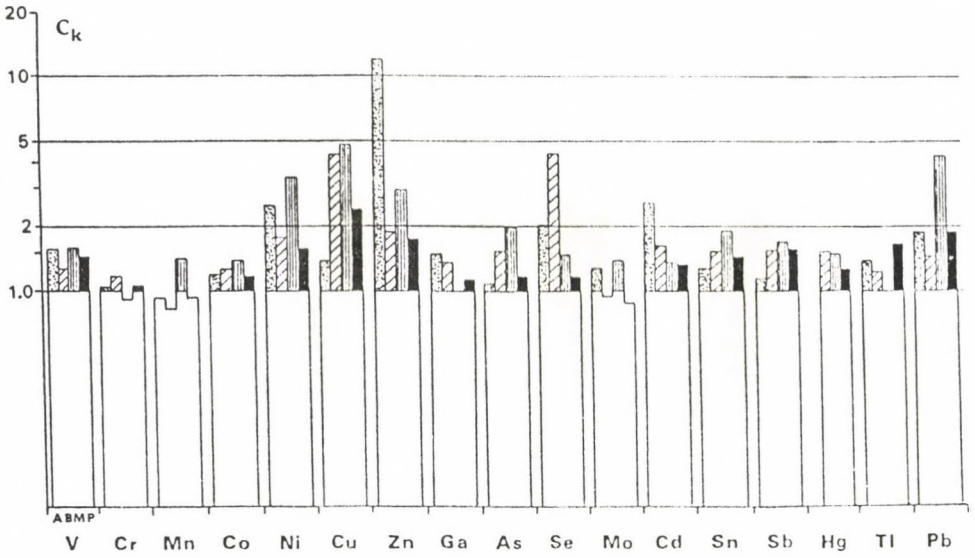

Fig. 1

Concentration distribution ratio for the elements calculated for fly-ash in the A-P/ < 60 μm and the A-P/filter fractions.

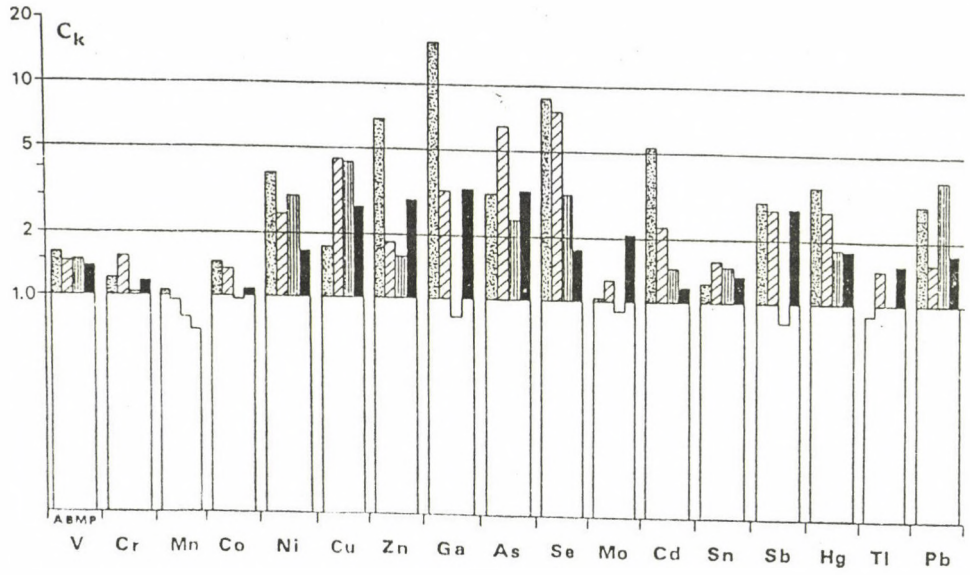

Fig. 2

Concentration distribution ratio for the elements calculated for fly-ash in the A-P/stack and the A-P/filter fractions.

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KFKI COMPUTER SYSTEMS GROUP

The members of the KFKI Computer Systems Group have been working for 25 years in the field of information systems, laboratory and industrial data acquisition and automation, computer aided design, image processing and network systems. The Group has succeeded in becoming one of the most important Hungarian firms providing high quality systems and services to government, scientific laboratories, public utilities, industry, and the commercial world.

The range of activities of the different companies within the group is very wide. It includes consulting, problem analysis, systems design, systems building and integration, installation, after-sales services, networking, software tools, application programs, turn-key solutions, etc.

One of the most important of the Group's achievements is that keeps pace with the needs of its customers. The predecessor of the group, the Research Institute for Measurement and Computing Techniques, was founded in 1955 with the main aim of developing electronic measuring instruments and measurement methods for nuclear scientists. In the sixties, with the increasing demand for small computers in the laboratories and their lack of availability, the institute developed and started to produce them. The first commercially available Hungarian computer was the result of this project. In the seventies the customer base became wider: government offices and agencies, public utilitites, industrial firms, etc. used the computers, the information systems, and other applications developed in the institute. Hardware production had to be solved as well. More than one thousand computer systems were produced and installed. The information systems for several government agencies and public utility companies were designed and installed by our experts. They also designed and produced the picture processing system of the Vega space mission, which provided pictures of Halley's comet. Our industrial data acquisition and control systems have mainly been used in power plants and energy distribution systems, such as the Paks Nuclear Power Plant.

As Hungary is entering a new political and economic era, the needs of the customers are rapidly changing. On the one hand, modernization of the country is

rapidly speeding up, which first of all means utilizing computers in almost every field of life. On the other hand, the possibility of buying up-to-date technology is becoming easier and customers are looking for solutions with optimum price-performance ratio. The Group has therefore strengthened its application oriented services, and the development and manufacturing activities are now concentrated on special devices.

Though our market is primarily on Hungarian customers (our share of the market is about eight per cent), well over a quarter of our systems were purchased for use abroad.

In order to provide an effective basis for dealing with the above mentioned areas, a number of the activities of the institute have been placed in the hands of autonomous companies, each geared specifically to address a particular area of the information processing market. As profit oriented business units with specific capabilities, these companies can easily work together on large, complex projects.

In its role as the holding company (apart from providing some common marketing and main contracting services) the KFKI Computer Systems Corporation coordinates the work of these companies.

The necessary research and development functions of the Group are covered by the Research Institute for Measurement and Computing Techniques. This is a non-profit research and development organization, but it also has close links with the holding company and the business units, listed below.

The KFKI Computer Systems Group (comprising the holding company, the business units, and the research institute) has about 500 full time employees and an annual income of about 30 million USD.

The business units (with their main profile) are the following:

- CADserver Ltd, providing turn-key CAD and CAM systems;
- DIREKT Ltd, an engineering company mainly for systems building, installation and servicing of micro- and minicomputer systems;
- IBIS Ltd, delivering IT services primarily to the financial industry;
- ICON Ltd, an off-shore company selling computer equipment and related services;
- ISYS Ltd, a system integration and engineering company providing services in the commercial business area;
- ITEA Ltd, an engineering company that designs and manufactures electronic systems and sells professional electronic equipment;
- KFKI Computer Networks Ltd, designing and installing computer networks of various types;
- LIAS Ltd, a system house specializing in laboratory and industrial data acquisition and automation systems;
- RASTER Ltd, designing special application systems mainly using signal processing and image processing techniques.

KFKI
RESEARCH INSTITUTE FOR MEASUREMENT AND COMPUTING TECHNIQUES (MSzKI)

Research Activities

1. Computer architecture

The Institute started research and development in the field of minicomputers in 1968. Since then the main trend of development was always connected with minis.

In the second half of the eighties the research work focused on parallel processors - hardware, software and applications. After gaining experience with an architecture comprising several VAX machines a new project started with a course grain architecture based on RISC microprocessors and using UNIX. The final goal of this project is a 16 processor computer with a performance of several hundred MFLOPS.

2. Computer networks, data communication protocols

In the field of computer networks Local Area Networks (specially Ethernet type) were the main fields of interest of the Institute. The work was mainly practical - how can different types of computers, operating systems, network architectures and protocols work together in an integrated system.

The development of protocol engineering methods started with the formal description techniques of communication protocols. This work achieved two results. As more and more computers are connected into networks, the importance of conformance testing of protocols increases, and the new developments are helping to solve this problem. The other result is a protocol consulting system, which helps to implement new protocols.

3. Picture processing, methods, equipment and application

The institute has about twelve years of experience in picture processing. The latest development is an Image Processing Workstation connected to a standard personal computer. The special processors, high capacity microprogrammed picture memory, and high processing speed are the main features of this sophisticated workstation. The software system of the station comprises about 50-60 picture processing and utility modules.

Application areas are mainly in industrial quality control.

4. Real-time systems, laboratory automation

When the Institute was founded, computer aided laboratory automation was the main activity. In the seventies and first part of the eighties development was based on the International CAMAC standards. Lately VME, MultibusII and the PC-bus are the standards used by the modules and equipment designed in the Institute. These modules are specially built for different applications in the nuclear, biomedical, accelerator control and other industrial and laboratory fields.

The institute also provides integral solutions in the laboratory environment. The largest project was the automation of the T-15 tokamak at the Kurchatov Institute in Moscow. This system has 14 minicomputers, 51 microcomputers, and 1500 CAMAC modules, which process about 10000 analog and digital signals.

5. Industrial automation

The institute has developed several industrial automation systems, mainly in the field of power plants, energy distribution and computer aided design. The most important results were achieved in the Paks Nuclear Power Plant, where the reactors and blocks are equipped with information and automation systems of the institute. A full scale training simulator for the plant was designed together with the Finnish firm NOKIA.

6. Simulation

A research group in the institute works on simulation methodology, algorithms and system architecture. A new, demon-controlled methodology uses a distributed knowledge base and monitoring; this system can modify the structure, parameters and experimental conditions automatically during the dynamic simulation process.

7. Software technology and knowledge based systems

There is an increasing activity in the institute using software technology methods in developing large software projects. In connection with this a research group works on improving methods and devices and on combining them with knowledge based systems.

The institute has close connections with Hungarian universities. About 25 research fellows give courses at different faculties, and there are always a number of postgraduate students preparing their theses at the institute. In the past couple of years seven professors of the institute held lectures at German, Canadian, US and French universities.

High-Speed Parallel Pipeline Image Processing System for Industrial Quality Control

István Erényi and István Rényi

Automatic inspection and quality control of industrial goods are of rapidly increasing importance in production. Visual inspection performed by humans curtails detection reliability of defective products due to inattentiveness and fatigue. As a result of these disadvantages, it seems highly probable that the application of automatic inspection systems will find little resistance from industrial management. The use of texture analysis methodologies seems to be adequate if quality is defined in terms of surface image irregularity: i.e. local inhomogeneities, impurities, variations of the "period length", tears, cracks, etc. Texture analysing techniques may be applicable for automatic inspection of textile web, paper, sheets of metal, wood, etc. (e.g. a normal textile web is characterized by a regular and visually homogeneous structure). Deviations in the textural structure exceeding certain tolerance thresholds are detected automatically on-line by the quality control image processing system. Some of the typical web defects are missing thread, loose thread, decrease or increase of inter-thread distance, thinner or thicker yarn, irregular weave, dirt, etc.

In the field of industrial quality control, real-time processing requirements and spatial resolution often lead to input data rates several times exceeding 10 million pixels/sec. High input data rates demand very high processing throughput. At our institute, a high-speed special purpose machine vision system is under development to meet the needs of real-time inspection and qualification of textile materials.

One of the main theoretical difficulties in texture analysis is the selection of measures or features that are suitable for describing the texture and for efficient computation. With real-time inspection, this latter condition means feasibility of implementing the algorithm directly into hardware. A lot of approaches have been proposed in the literature for describing textural properties which work more or less well [1], [2], [3]. Methods based on second order statistics are excellent from the viewpoint of texture analysis properties, however their calculation intensive nature means that their implementation by pure hardware is not feasible.

Our choice fell on an algorithm that does not require calculation of second order statistics [2], [3]. Texture characterization using this algorithm consists of two steps: first, 'primary' features are computed (enhanced) using filters over microwindows. Local neighbourhood properties are enhanced by filters or filter matrices (of, say, 3*3 or 5*5 elements), performing local convolution with pixel values of the input texture. Convolution may be done by VLSI circuits [4] capable of executing complex convolution operations on n*n windows (usually n = 3, 5 or 7) at rate of more than 20 MHz. The outputs of the filters are called 'primary' feature planes. Secondly, microstatistic features are obtained over larger, so called macrowindows (8*8, 12*12 or 16*16 pixels). The most useful microstatistic values

are the sums of absolute or squared values of the 'primary' feature planes. Microstatistic calculations are relatively simple arithmetic operations easily realizable in hardware. The values of the microstatistic calculations for a macrowindow of all of the "primary" feature planes form a feature vector. Feature vectors reflect the properties of macrowindow areas.

On the basis of feature vector values, macrowindow areas may be classified into "healthy" and "faulty" categories. Faulty location coordinates may be forwarded to a geometrical/morphological error classification algorithm. Since the data rate of faulty macrowindow areas is many orders of magnitude less than the input data rate, this classification is done by software means.

Prior to hardware development, careful simulation work was needed in order to prove the adequacy of the selected type of algorithms as well as to find the right convolution/filter coefficients, and microstatistic calculation types and feature vector evaluation methods for every type of textile material. During simulation the ARGUS Image Processing Workstation [5], [6] was used to digitize textile sample images and store them in the memory of the system. ARGUS software library routines provided a useful and efficient environment to run, test and evaluate a variety of filtering, statistical and feature vector classification parameters and methods.

Even though, during simulation, we did not succeed in finding any adaptive methods for "learning" the properties of the textile web to be inspected generating thereby automatically the parameters by machine, we did successfully identify a heuristic set of these parameters for any textile type. This set of parameters may be stored in files attached to the type of textile and then, before inspection starts, the file can be downloaded to the texture analysing hardware depending on the type of textile web to be inspected.

The simulation work provided promising results for automatic textile-web inspection. On the basis of this, we started the hardware development directly implementing the selected algorithm. In the inspection machine sophisticated signal and image processing VLSI circuits and ASIC devies are to be used. The development is planned to be finished and the equipment installed for real environment tests at textile plants in 1992.

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Demon Controlled Simulation for Efficient Problem Solving

András Jávor

A methodology for enhancing efficiency of problem solving by controlling simulation with intelligent demons is proposed. A simulation system in which the principles described have been implemented is introduced.

The process of simulation usually consists of a recursive series of simulation runs. After each experiment with the model, the results are evaluated and the experiment - using modified experimental conditions and/or models - repeated. The problems to be solved generally fall into two categories: (i) *system identification or behaviour analysis*, (ii) *reconstruction*.

The efficiency of simulation can be increased considerably by delegating the task of evaluating the results of simulation and consequently modifying the experimental conditions of simulation and the model itself using a mechanism that includes a knowledge base and an inference engine.

The steps required to control simulation based on the evaluation of simulation results include

(i) information collection from the results obtained during the dynamic simulation run,

(ii) possible postprocessing of the results,

(iii) evaluation of the primary results, or of the secondary ones obtained through postprocessing,

(iv) intervention based on the results of (iii) and matching them against the information stored in the knowledge base.

The actions described require continuous monitoring of the simulation run. The idea is to insert demons to monitor the various parts, i.e. state variables or secondary parameters of the model [2]. The demons are evoked by certain events such as the changing of the values monitored, or secondary ones derived from them by postprocessing, as well as certain time values. In this way the demons continuously obtain information on the state of the model. The interventions can be activated by the events at data collection times or independently evoked by other events.

The implementation of the principles described can be realized using an *object oriented* approach. It is not only the simulated model itself that should preferably be built in a distributed way but also the control of the simulation experiment. In many cases the main aim of the simulation study is achieved by dividing it into a number of local subgoals. Using such - heuristic - methods complexity of problem solving can be reduced drastically. As an example let us consider the traffic control of a whole town. Obviously, the complexity can be reduced considerably by subdividing the adjustment of traffic control into blocks or districts so that in each decision the state of remote parts of the model is neglected in first approximation. Nevertheless, the model as a whole is simulated and if some

unexpected event in a remote area affects the relevant part of the model, it will be identified and can be corrected. A similar treatment of problem solving seems to be reasonable in many other fields, e.g. complex economic systems, logistics, computer networks, multiprocessing architectures. Thus a number of demons can be inserted to monitor various parts of the model with the ability to intervene by modifying the model structure, the model element parameters, or the input stimuli of the model during simulation. The individual demons have their own *local knowledge bases* that can be used to make decisions. At the same time a *global knowledge base* that can be accessed by any demon monitoring and controlling the simulation experiment can be made available to contain knowledge about the state of the simulation as a whole.

The above principles have been implemented in a simulation system intended for use in a wide range of applications. The CASSANDRA (Cognizant Adaptive Simulation System for Applications in Numerous Different Relevant Areas) system enables the rapid and economical development of user-oriented special purpose simulators in a large number of application fields by adding problem oriented communication interface layers and modules, providing for the partial automation of the investigations by simulation - thereby considerably increasing effectivity. Using intelligent demons CASSANDRA continuously evaluates the results of dynamic simulation, modifying the experimental conditions, the structure and parameters of the model according to the actual goals.

The results achieved in implementing the principles in the CASSANDRA system and testing it on models from various fields of applications such as producer/consumer systems, logistics, communication protocols and FMS have provied promising results.

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XRL: A Shell for Building Knowledge-Based Systems

Bálint Molnár

1. Introduction

We should like to present a short overview of the XRL systems originally developed in Rumania by Barbuceanu and his team. This system was implemented in a special dialect of LISP running on PDP-11 compatible machines. We combined our efforts and tried to port the existing system to a VAX compatible machine in order to exploit the standardized Common Lisp and the 32-bit architecture. As time

passed the XRL incorporated more and more interesting features and provided an immense amount of experience. After having successfully ported to VAX compatible machines we began to compile a User's Manual and a Language Reference Manual.

XRL (Schema Representation Language) is a hybrid multi-layer architecture in which lower level tools such as structured objects, production rules or prolog are contained in the lowest layer. The middle level tools themselves represent an XRL specific layer including concurrent refinement of structured object and set oriented refinement. The upper layer incorporates the XRL specific approach to the construction and enhancement of knowledge processing tools or domain models. The self generation tool at this level plays an important role by extending the XRL network abilities relating to the structured objects and to the knowledge processors.

We have presented our ideas at several conferences.[1,2,3,4]

2. The architecture of XRL

2.1 The lowest layer

The lowest layer has the - so called - structured object substratum containing the XRL structured objects that are similar to the widely known frame concept in AI, or to the objects in the different object-oriented programming paradigms but they have a lot of specific and very advanced properties.

The traditional attributes of the structured objects can be summarized as follows:

- multiple inheritance
- meta-objects
- message passing with method combination
- active data (triggers)

The new aspects of the structured objects in XRL are the following:

- the extended method combination abilities - XRL can combine the inherited methods with methods from the same lexical context
- the definition of XRL types for consistency checking and associative retrieval
- the special language defined for accessing the element of a network consisting of structured objects
- ADT or abstract data type facility showing the relation between XRL and object-oriented philosophy and in addition providing for system interfacing and data handling capabilities

2.2 The middle layer

A powerful and widely used mechanism for bringing to bear the knowledge encoded in structured objects is instantiation, a procedure by which the knowledge

contained in a generic object is employed to construct a similarly structured terminal object. In spite of the ubiquitous occurrence of instantiation in frame systems, only few languages support this process explicitly.

The middle layer of XRL delivers two tools that implement frame instantiation. The formalized instantiation process is called refinement. The first tool is based on interpreting structured objects as specifications of loosely coupled concurrent refinement processes, each process producing an instance of its generic unit. The second introduces a set theoretic language of descriptions which extends the structured object language, yielding an axiomatic way to instantiate the emerging notion of structured object, and provides the machinery to implement the new instantiation concept on top of the former concurrent refinement tool.

2.3 The upper level

The explanatory knowledge processor construction and enhancement endorses the construction and enhancement of a wide range of such processors, from independent low level domain ones such as production rule systems, through middle level ones such as the concurrent refinement one and up to task level ones such as design systems. All these sorts of processors are called domain models.

The theory and tools in this layer assume a certain characterization of domain models. From a representational point of view, they are assumed to be structured object languages characterized by certain vocabularies of slots and object types, together with an interpreter that is able to process the types of structured objects and slots defining the language.

The object oriented nature of domain models hides in fact a commitment to data-driven programming. The approach appears to be suitable for data-driven programming where relevant parameters of the programs are explicitly represented and are accessible as data structures with possible procedural annotations.

The approach consits of two main steps. The first step uses: (1) a prototype version of the model, (2) a number of parameters of the model, (3) explicit specifications of the assumptions made about these parameters.

The parameters and assumptions, together called explanatory structures, can be extracted from a data base which holds programmer defined or system derived explanatory structures. These elements form the basis for re-formulating the model in a form suitable for the second step. Essentially, this form is functionally equivalent but it explicitly represents the dependences between assumptions, parameters and the content of the model. These dependences show how parts of the model depend on given assumptions and parameters.

The second step uses the re-formulated model as basis for a base for a number of "semantic editing" activities which modify the assumption and/or parametes and propagate the effects of these modification on the model. The result is production of the new models which work under the modified assumptions and/or parameters. A second result is production of new explanatory structures by modifying the previous ones. These are achieved in the explanatory structures data base. Semantic editing activities are possible because the re-formulated - or

explained - form of the model explicitly links the relevant assumptions and parameters with the parts of the model that depend on them.

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Several research reports published by KFKI contain detailed information about the system.

TPA XP-1 16-processor, Shared Memory MIMD Computer

György Matakovics

A usual method for increasing the efficiency of a computer is to increase the performance of the processor; however, this is limited by current technology. Another possible solution is to disclose parallelism within a given task and to solve the task parallelly on more than one processor, or to run several application programs simultaneously on more than one processor in a multiuser operating system. The above said explains why multiprocessor computers are gaining more and more ground. This way of development is shown by large computer firms (IBM, DEC, Cray) as well as manufacturers of special computers of smaller series (Elxsi, Thinking Machines, BBN, Ncube, Encore, Convex, FPS).

During the last five years, production of such computers increased yearly by an average of 26% while only by 5% in the mainframe category. Almost half of all installed mini/mainframe computer systems have parallel architecture by the end of 1991. This means that several processors work on one or more programs parallelly, thus increasing the system's throughput. Parallel systems are suitable for geophysical and molecular biology research, in the field of chemistry, circuit and other simulations, signal and image processing. Multiprocessor systems are also used in financial modelling and data base management.

Parallel architectures have many advantages:

modularity - using processor elements of the same type a wide range of performances can be covered, and, if the user's demands increase, further processors can be added to the configuration,

reliability - the system remains operable even if certain processor elements break down;

super performance - this can be achieved by arranging a system parallelly: when the fastest possible processor is made the next step is to interface two of them, in other words to arrange a multiprocessor architecture; in the case of high-performance multiprocessor systems made from relatively cheap microprocessors a better *price/performance* ratio is obtained - except for the low-end category.

Some problems of parallel processing systems

The present multiprocessor systems can be classified by memory architecture into three groups:

Tightly coupled sytems - in such systems all processors share the same physical memory the whole of which is available for all processors; peripherals are available for all processors (occasionally indirectly). In tightly coupled systems the operating system (code and data structures) exists only in a single copy in the memory, which can be accessed by any other processor. In such *shared-memory* systems there is no need for separate communication between processors because common variables are available for any processor by a memory reference instruction realizing an implicit communication method.

In *snugly coupled* systems (it is also called NonUniform Memory Architecture) several processor cards (any of them can be a tightly coupled multiprocessor system) are interfaced by a common bus; any processor has its own memory, which is not available for other processors; the global memory, which is accessible from each processor, is on a separate memory card.

In *loosely coupled* systems several computers (any of them can be either a snugly or a loosely coupled multiprocessor system) are interfaced by a local network (e.g. Ethernet, hyper cube); it has not any common memory; peripherals interfaced to a computer are usually available for any other ones. Any computer of this type has its own operating system but there is no global memory.

In such *local memory* sytems information exchange takes place explicitly, through a local network. If any processor needs calculation results from any other one, it should be mailed. The duration of communication is in the millisecond range, which is remarkably slower than that in a tightly coupled system. Here, each member of the system has its own operating system, which communicates through a common memory. Communication can take place either through a common data base (implicit) or in the form of message passing (explicit).

From the viewpoint of programming, *shared memory systems* are advantageous because of implicit communication. Programmers do not have to pay extra attention to send results from processor to processor, they should only

be aware that there will be a result by the time it is needed. In the present shared memory systems the main problem is caused by the access time of the memory being slower than the cycle time of the processor and thus in the case of the same memory unit there is no opportunity for two or three processors to operate concurrently. Namely, if there is a great number of processors a fast performance decrease happens as more and more processors want to reach the same memory unit (*memory conflict*) even if their traffic is minimised by cache techniques.

A further problem may be caused by the bandwidth of the interconnection between processors and memories because - depending on its arrangement - a situation of collision can occur (*interconnect conflict*) which leads to further performance decrease.

In *local memory* systems there is no memory conflict and thus they are allowed to consist of a great number of processors. However, they may also have some disadvantageous characteristics: none of the processors is able to communicate directly with any of the others. Complexity of the communication network is quadratically proportional to the number of processors. In order to achieve lower complexity the whole communication network is not usually realized. Thus communication between processors becomes indirect, namely the data reach their destination through intermediate processors increasing thereby the length of communication. A further problem involved is that *explicit* communication increases software complexity thus decreasing performance.

TPA XP-1 multiprocessor

TPA XP-1 is a *shared memory, tightly coupled* multiprocessor system. Its processor hardware is of general purpose, it is not specialized for any use. Its flexible architecture enables all accessible processors to work together even in the case of a single application.

Its architecture consists of 16 processors. The processors are completed by a floating-point coprocessor, which - by virtue of its high performance - may substitute the vectorprocessor. 64 Mbyte memory corresponds to each processor which is part of the global memory and is accessible for each processor. The large and high-performance crossbar memory system can be extended up to 1 Gbyte.

The console subsystem of the computer provides customary console functions, serves diagnostic purposes, and performs error logging for the operating system. With its help the computer can be put into a remote diagnostic network in order to increase availability.

Hardware

Processor/memory interconnect

In shared memory multiprocessor systems data traffic between processor and memory units takes place through an interconnect network. Several types of interconnects exist, e.g. bus, multiple bus, Multistage IN, Crossbar IN. Conflicts arising from the use of interconnect significantly decrease the resulting performance of the multiprocessor system. This shows why the type of interconnect should be considered thoroughly and optimized to data traffic and the number of processors.

Crossbar interconnect

TPA XP-1 interfaces 16 processors and 16*64 Mbyte memory through two one-way crossbar networks. The whole memory is physically shared among processor elements, in order to simplify the use of the cache technique. The whole memory is accessible for any processor, however, processors reach their own memory not through the crossbar interconnect, but in a local way. The processor-cache has an effect only on local accesses. The architecture consists of two one-way crossbar interconnects, one from the processor to the memories and another from the memories to the processors. Crossbar data paths are each 40 bits wide in each direction with 32 data, parity and hand-shake lines.

Processor

MIPS R3000/R3010 type microprocessor is one of the best microprocessors due to its relatively low frequency (25-33 MHz), high scalar (20-27 MIPS), and very high floating-point DP Linpack performance (3.9 MFLOPS), its large cache memory size and multiprocessor support. The R3000 chip consists of a central processing unit, 32 registers each of 32 bits, a memory management unit, cache and memory controller logic, and manages 4 Gigabyte virtual address space. An R3010 tightly coupled floating coprocessor extends the R3000 by floating-point instructions and operates with single (32 bit) and double (64 bit) precision data format in accordance with IEEE standard 754. The processor unit of TPA XP-1 is built on R3000 which operates on 40 nsec cycle time. The 128 Kbyte cache memory (64 Kbyte instructions, 64 Kbyte Data) operating by physical addresses consists of SRAMs of 20 nsec access time. The two caches work so that they overlap in time. This ensures 200 Mbyte/sec bandwidth of the cache, which is needed for the processor to work without waiting state. The cache memory is write-through, directly mapped. Automatic consistency is ensured only at data-cache. Instruction-cache consistency is ensured by software (cache flush). In order to increase the hit rate of the cache there is a 4-word, so called "look-ahead" (block refill). "Instruction streaming" mode that enables the instruction to be performed at the time of I-cache refill.

The connection between the processor and the memory is a 100 Mbyte bandwidth, synchronous local bus. The crossbar interface and the optional I/O interface are connected there. Total transfer bandwidth of interconnect is 1280 Mbyte/sec by 16 node. With the help of the optional I/O interface the processor is able to manage peripherals through any standard I/O bus. At present VME, the most widely known I/O bus is used.

The CPU card contains a 512 Kbyte Monitor program, which is burnt in EPROM. It contains power-up diagnostics and enables the CPU to operate under control (memory write/read, loading operation system, loading and starting standalone programs, etc.)

Memory

One memory module of XP-1 operating synchronously with the CPU is of 64 Mbyte capacity by using 4 Mbyte dynamic memory units (DRAM). Using 25 MHz system clock frequency the VLSI programmable DRAM controller ensures a 160 ns access time.

A memory module consists of four independent 16 Mbyte units. It is interleaved four times, namely there is an opportunity to read four words of 32 bit each from sequential addresses.

Error control is ensured by a 14/20 nsec EDAC (Error Detection And Correction) circuit - which is a basic safety requirement. It corrects single errors and signals multiple ones.

Supervisory system

The supervisory system monitors environmental conditions of the operation of TPA XP-1 multiprocessor and intervenes if necessary. It measures environmental temperature, the temperature difference between in- and outflowing air, the ventilation, the voltage level of the power supply units, the quality of the grounding system (ground current).

Technology

Circuit elements of TPA XP-1 multiprocessor are High-speed CMOS based. The 64 Mbyte memory and the processor module are mounted on a 12-layer printed circuit board. Their current supply is ensured by 48V/5V 30A DC/DC converters mounted on them. The back panel is assembled from both sides and has 14 layers. Interconnect cards are of 6 layers with a current supply ensured by the processor units.

Software

The operating system of the XP-1 computer is the multiprocessor version of the UNIX operation system. "Version" does not mean another (non-compatible) UNIX system, merely an adaptation of an existing (AT&T System V Release 4) system to the multiprocessor TPA XP-1 configuration.

User requirements of adaptation:

– *Portability of programs*

Existing programs (application programs, compilers, libraries, etc.) should be able to be used in the adapted system without any modification. Adaptation should "hide" TPA XP-1 multiprocessor architecture from these programs.

– *Supporting of multiprocessor applications*

Adaptation should enable applications that explicity require a multiprocessor environment. Simple portability cannot be expected - as there are no standards - and System V adaptations tailored to other multiprocessor systems are regarded as a norm.

– *Hardware requirements of adaptation*

TPA XP-1 architecture is situated between tightly and loosely coupled systems, because the whole physical memory is available for each processor, but

a part of the memory corresponds to any processor which seems to be local (from the point of view of access time). TPA XP-1 architecture is symmetric: any of the processors can perform input/output tasks. However, in practice more than one, occasionally two, input/output processors are needed. Hence XP-1 architecture becomes asymmetrical - at least from the point of view of the operating system.

The operating system has thus to be prepared for the following cases:

- Configuration is fully symmetric, each processor performs both input and output tasks.
- Configuration is fully asymmetric, all input/output tasks are performed by single processor. It can be a "dedicated" input/output processor, which deals only with input/output operations.
- Any quasisymmetric configuration between the two extreme cases. This means that the operating system should be dynamically reconfigurable. It requires the functional separating of the operating system kernel functions between processors.

Kernel functions

1. System calls

System calls determine the surface of the operating system "visible" from the side of the application programs. Consequently, system calls determine the operating system (e.g. System V, its version, etc.).

Serving the majority of system calls requires services from other functional areas (e.g. input/output, scheduling, etc.), however, system call definitions fully belong here. Bearing in mind the wide utilization of UNIX systems, the "natural" place of algorithms serving system calls is the local memory of each processor. This means that these algorithms exist in as many copies as there are processors.

2. System services

System services that are invisible to the user (or, which should be invisible, but are independent of the interface) belong here.

System administration has both processor-dependent and independent functions. An example of the latter is the serving of hardware interrupts (excluding input/output interrupts which are managed as separate functions).

The case of processor-dependent functions is fairly unambiguous: interrupts can be software or hardware errors. Software errors (usually fatal ones) can arise either from the operating system (system crash) or application programs (program abort), their service is in no way time critical. The size of the service code determines whether it is worth storing it in a single copy (anywhere) or whether there is "enough space" for it in more than one copy, in the local memories of each processor.

However, the serving of hardware errors is connected with the local memory: an interconnect error cannot be managed by a procedure whose code is in a "remote" memory, and it would be reached only through the (faulty) interconnect.

The case of processor-independent functions is not so simple and it is impossible to come to a final decision without performance investigations. A major difference from single-processor systems is that resource management is not restricted to one processor; balanced loading of processors should be ensured. Process migration with all its problems is inevitable.

3. Input/output services

Input/output procedures belong here; they are independent of the type of peripheral (class drivers). For example, in the case of each disc peripheral there is a need for buffer management, but its algorithm is independent of the type of disc unit. These management functions also have their natural place: the local memory of processors to which the given type peripheral is interfaced.

4. Peripheral management

Here belong the procedures operating the peripherals directly (port drivers). The natural place of these procedures is the local memory of the processors to which the peripheral is interfaced.

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KFKI
INFORMATICS CENTRE
(IK)

Computing Services

At the beginning of 1989 the former Computing Centre of KFKI was reorganized to continue working under the name Informatics Centre. The Informatics Centre is responsible for managing the networking infrastructure and the central computing facilities of KFKI. The main activities of the Informatics Centre were concentrated on providing computing services for the entire KFKI and some other organizations of the Academy of Sciences as well as on carrying out scientific research in the field of numerical and non-numerical applications of computers and in mathematical physics.

The central computing facilities in the Informatics Centre are

- a BASF 7/61 type fully IBM 4361 compatible mainframe installed in 1988 running under the OS/VS1 operating system and GUTS (Gothenburg University Timesharing System), which provides the facility of interactive compilation and program execution.
- two TPA 11/500 type VAX compatible supermini computers running under the VMS operating system, one acting mostly as a file server, the other as a gate-way for the external network.

In the year 1989 a moderate-sized Ethernet type local area network was built, to which several hosts are connected. The hosts are mostly VAX compatible TPA type supermini computers (VAX clones) and IBM PC clones (XT and AT compatibles). The BASF 7/61 computer is connected to a TPA 11/440 computer in the network via a channel-to-channel adapter developed in the Research Institute for Measurement and Computing Techniques. The services available in the local area network are: electronic mail, file transfer and login to remote computers in the network. By the end of 1990 the number of nodes in the network had reached 350, the number of simultaneously active nodes in day-time being about 70-75 out of which the number of multiuser nodes was about 24-26. The average total traffic is currently 60-80 MByte/day.

At the beginning of 1990 the local area network of KFKI was connected to the X.25 wide area public packet switching network of the Hungarian PTT via a gate-way computer, thus making available electronic mail services and login to

At the beginning of 1990 the local area network of KFKI was connected to the X.25 wide area public packet switching network of the Hungarian PTT via a gate-way computer, thus making available electronic mail services and login to remote computers in the wide area network for the scientific community of KFKI. Electronic mail to and from sites in Hungary is provided by the ELLA Electronic mail software developed with the support of the Information Infrastructure Program. The interfacing program making available the services of ELLA for all users in the local area network was developed in our Institute. There is also a connection to the international Eunet (European Unix network) network via the ELLA system, thereby making world-wide electronic mail services available.

On-line information retrieval services are available on the BASF computer. The bibliographical data bases BIBOR and OPAL (cf. next section) are based on the CDS/ISIS data base management system. The date bases are also accessible via the X.25 network. By means of the X.25 network it is also possible for users to reach those data bases in Hungary developed with the support of the Information Infrastructure Program as well as international data bases for on-line information retrieval.

Computer Applications

The main activities were devoted to numerical mathematics, computer algebra, information theory, theoretical neuroscience, development of bibliographical data bases and the applications of informatics.

In the field of numerical mathematics, rational approximations have been investigated for some special functions of mathematical physics. New methods have been developed for generating conjugate directions with respect to arbitrary matrices.

The Informatics Centre together with the Department of Genetics and the Department of Plant Taxonomy and Ecology of Eötvös University have continued their cooperation to develop models of biological evolution.

In cooperation with the Institute for Atomic Energy Research improvements have been made to the algorithm applied in the ANICELL nuclear reactor neutron transport code which solves the traditional asymptotic and the so-called tilted flux transport problems in one-dimensional cylindrical geometry using linearly anisotropic scattering. Some methods for the iterative solution of linear equations have been developed for use in nuclear reactor physics.

With regard to computer algebra, in addition to the version of the REDUCE language used on IBM compatible mainframes a version of REDUCE has been installed for IBM PC's, too. The REDUCE Library which is accessible through electronic mail is now available.

An experimental package written in the REDUCE language was developed. This manipulates tensor expressions symbolically in general relativity calculations. In the package, tensors are considered as symbols without referring to the actual components. Tensor equations are handled by using the rules of tensor algebra and the properties of differential operators. A new output switch was introduced in order to keep to the standard notation for tensor expressions.

Concerning information theory, a new encoding algorithm within the family of variable-length-to-block encoding processes was developed. The efficiency of the new code has theoretically been proven for a memoryless source. Several computer programs have been written to test the encoding algorithm and to generate optimal encoding schemes.

Our work in theoretical neuroscience is aimed at the mathematical modelling of motor control in humans and in monkeys. Several computer programs have been developed for modelling movements of the musculo-skeletal system in terms of a multidimensional geometric theory of neural systems. It is thought that results may find a practical application in robotics and in the medical rehabilitation of the handicapped.

Several bibliographical data bases have been built for information retrieval. The BIBOR (BIbliographical data base BOoks and Reports) data base contains details of research reports in the central library of the Institute. The OPAL (Online ProgrAm Library) contains data of programs in the program library of the Informatics Centre. Both data bases are accessible online by users of the wide area network.

A data base has been set up for recording the products, contracts and accounts of the Research Institute for Measurement and Computing Techniques (MSzKI). On the basis of this data base an information system has been developed to support the management of MSzKI.

As far as applications of informatics are concerned, there are two fields which should be emphasized here:

- research and development in information technology with particular emphasis on their impact on organizations and strategic decisions;
- investigation of project management in complex information systems, in which the main point is to achieve a balance of hardware, software and orgware. The results can be used to develop project management methods for practical applications.

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- **L.** Vibration Analysis, CAD, CAM
- **M.** Hardware and Software Development, Computer Applications, Programming
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